AD-777 299

AIRSICKNESS IN AIRCREW

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

FEBRUARY 1974

AGARD-AG-177

AD777299

AGARD-AG-177

AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

7 RUE ANCELLE 92200 NEUILLY SUR SEINE FRANCE

A' ARDograph No. 177

on

Airsicl. :ess in Aircrew

by

T.G.Dobie

DDC

RECEIVED

APR 29 1974

D

NORTH ATLANTIC TREATY ORGANIZATION

NATIONAL TECHNICAL INFORMATION SERVICE

DISTRIBUTION AND AVAILABILITY ON BACK COVER

DISTRIBUTION STATEMENT A

Approved for public release; Distribution Unlimited

NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARDograph No.177

AIRSICKNESS IN AIRCREW

by

T.G.Dobie

Department of Physiology
University of Leeds
Leeds, UK

This AGARDograph was sponsored by the Aerospace Medical Panel of AGARD.

THE MISSION OF AGARD

The mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

- Exchanging of scientific and technical information;
- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving the co-operation among member nations in aerospace research and development;
- Providing scientific and technical advice and assistance to the North Atlantic Military Committee in the field of aerospace research and development;
- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field;
- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;
- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community.

The highest authority within AGARD is the National Delegates Board consisting of officially appointed senior representatives from each member nation. The mission of AGARD is carried out through the Panels which are composed of experts appointed by the National Delegates, the Consultant and Exchange Program and the Aerospace Applications Studies Program. The results of AGARD work are reported to the member nations and the NATO Authorities through the AGARD series of publications of which this is one.

Participation in AGARD activities is by invitation only and is normally limited to citizens of the NATO nations.

The material in this publication has been reproduced
directly from copy supplied by AGARD or the author.

Published February 1974

616.859 : 358.432

Printed by Technical Editing and Reproduction Ltd
Harford House, 7–9 Charlotte St, London. W1P 1HD

PREFACE

This handbook is based on a study of airsickness which was carried out by the author in the Royal Air Force. It is intended to provide the reader with a working knowledge of this malady and an approach to its management which the author has found to be successful. Thus it is written in a simple and didactic manner and does not pretend to be a comprehensive survey of the considerable literature which is available on this subject. Although it is primarily related to an aircrew population and to trainee pilots in particular, many aspects of the problem are common to airsickness amongst passengers and to other forms of travel sickness. Where necessary, the author has augmented the original work to include guidance on specific aspects of the management of airsickness amongst passengers.

Airsickness is a malady brought about by certain kinds of aerial maneouvres and is characterised by a number of signs and symptoms which include pallor, cold sweating, malaise, nausea and vomiting. Since an identical syndrome can be caused by other forms of motion, many authors prefer to use the more general term 'motion sickness'. For example, Whiteside (1965) suggested that:

> 'as the terms "airsickness", "car sickness", and "sea sickness" all refer to a single entity and not to different illnesses peculiar to the mode of travel specified, there is much to commend the use of the general term "motion sickness" '.

In similar vein, Gillingham (1966) referred to motion sickness as follows:

> 'included in the general term "motion sickness" are airsickness, seasickness, train sickness, car sickness, amusement-park-ride-sickness and camel sickness'.

It is perfectly true that these (and other) various forms of transport are all capable of producing the same syndrome and the use of a common designation would appear to have advantages. On the other hand, the author believes that this practice can be misleading because it infers that all cases of 'sickness in the air' are induced by motion and can correctly be termed 'motion sickness'. There is evidence that this is not always the case (Dobie, 1970), and this will be discussed later. The author prefers to retain the more specific term 'airsickness' when dealing with this disability in the flight situation and will do so in this handbook.

Airsickness is a very common malady. The incidence has been reduced in the passenger population by the introduction of stable high flying aircraft, but it is still high amongst trainee pilots. It also causes a considerable wastage of effective training time in the air and thus represents a significant economic penalty whose magnitude is frequently not realised because airsickness has been associated with flying training, particularly in its early stages, from the very beginning of aviation. Flying instructors may come to accept a significant decrement of performance due to airsickness amongst trainee aviators without being aware of the overall magnitude of the problem.

In this handbook the author examines the problem in terms of loss of useful training time, as found in the Royal Air Force and presents figures which are likely to be typical of those which occur in any modern air force. Various methods of reducing this incidence are discussed as well as an approach to the management of flying personnel with airsickness. Readers will be able to adapt these recommendations to the particular conditions which exist in their own area of responsibility.

ACKNOWLEDGEMENTS

I wish to express my gratitude to the many people whose help and co-operation made my original study possible, in particular to Chief Technician Link who for many years gave unstinting help as turn-table operator and to Squadron Leader David Reader, Squadron Leader Tony Lister and Squadron Leader Gordon Smith, the three medical officer pilots who carried out the airborne rehabilitation phase of the airsickness treatment on my behalf;

to Air Marshal Sir Ernest Sidey, Director-General of Medical Services (Royal Air Force), not only for permission to publish this work, but in particular for his encouragement during the early part of the study when he was the Principal Medical Officer of Flying Training Command (sic);

to two other Principal Medical Officers of that command, namely Air Vice-Marshal J.S. Wilson and Air Commodore E.B. Harvey who gave me much help and without whose interest the study could not have been continued, particularly after I left that Command;

to Squadron Leader John Baird and Squadron Leader Douglas Smith, Medical Officers at Royal Air Force, Church Fenton and their staffs, who were particularly patient and helpful despite my many visits and other calls on their precious time;

to Messrs. Roche who generously prepared the trial tablets and necessary documentation for the drug trial;

to the many aircrew students who acted as volunteer subjects during the investigation of cupulometry;

to the patients who agreed to be treated and who have generously written to me during the follow-up phase so that I could monitor their progress;

to Miss Helen Ferris and her staff who gave advice and help in handling the large amount of raw data and in that respect also to Air Vice-Marshal H.L. Roxburgh, Commandant of the RAF Institute of Aviation Medicine for permitting that statistical work to be carried out;

to Dr. Alan Benson, Dr. Ken Money and Dr. Fred Guedry, distinguished workers in this field, who generously gave of their time to discuss my research programme and comment on its outcome;

to Dr. A.J. Benson of the RAF Institute of Aviation Medicine, Farnborough for acting as expert adviser on behalf of the Aerospace Medical Panel and in so doing, providing the author with valuable comments and recommendations for the final preparation of the handbook;

to Peter Banks and Peter Hargreaves for the preparation of the various figures and tables;

to Miss Jacqueline Atkinson who has typed and retyped the original manuscript so often that she must know this handbook by heart;

to the many others who have not been mentioned but who allowed access to documents, gave technical assistance and somehow managed to make time available.

I shall always be grateful to my wife and family who must have been heartily sick of my many absences collecting information.

CONTENTS

FIGURES

TABLES

SIGNS AND SYMPTOMS OF AIRSICKNESS

Money (1970) stated that the commonest signs of motion sickness reported in the literature are pallor, cold sweating, nausea and vomiting and that the most common symptom was nausea. He reported that there were many other symptoms and signs of this malady which affected a wide variety of systems in the body as follows:

(a) Signs of Airsickness

1. Pallor
2. Cold sweating
3. Vomiting
4. Reduced blood flow in skin, increased blood flow in muscle
5. Increased ventilation of lungs
6. Yawning
7. Inhibition of gastric motility and tonus
8. Salivation
9. Increased hemoglobin concentration in blood
10. Increased concentration of 17-hydroxycorticosteroids in serum
11. Increased rate of urinary secretion of catecholamines
12. Oliguria of the pituitary type
13. Fall of body temperature

(b) Symptoms of Airsickness

1. Malaise
2. Nausea
3. Epigastric discomfort
4. Drowsiness
5. Headache, especially frontal headache
6. Apathy
7. Feeling miserable or depression, especially with motion of long duration (hours)
8. Dizziness or giddiness

(c) Changes in Behaviour and Performance

1. Decreased spontaneity, inactivity, or being quiet or subdued
2. Decreased muscular co-ordination and eye-hand co-ordination
3. Decreased squeezing force in the hand
4. Decreased ability to estimate time
5. Decreased performance of arithmetic computation

It is clear from the foregoing lists that there are many signs and symptoms of this malady and in some circumstances it could be difficult to be sure that the less common of these were directly attributable to airsickness. For this reason, the author based his assessment of the incidence of airsickness amongst trainee aviators on the symptomatology most commonly reported. This approach had the further advantage that the diagnosis of airsickness could be readily made by either the subject himself (the student aviator) and/or an observer (the flying instructor). Both of these individuals were well aware of the common classical signs and symptoms of the malady. The severity of the condition was then assessed according to the degree of decrement in performance which it caused and not by a clinical end point such as different grades of nausea or vomiting as used by the majority of other workers in this field.

The author chose to measure the effects of airsickness in terms of a student's inability to perform his task for two reasons. Firstly, it highlights the economic penalties of airsickness and these are particularly significant to the executive authorities in the parent Air Force. Secondly, the author was well aware of the fact that many individuals who vomit are apparently able to carry out their task efficiently both immediately before and after vomiting. Others who report nothing more than malaise or mild

nausea are apparently reduced to such a state of inefficiency over a relatively long period that the training value of the trip is largely negated. Thus, it is more meaningful to assess the severity of a case of airsickness by the adverse effect which it has on flying skills rather than some relatively arbitrary assessment of the severity of signs and symptoms.

AETIOLOGY OF AIRSICKNESS

A wide variety of aerial maneouvres have been reported as precipitating airsickness. The most common of these are stalling, spinning, aerobatics and recovering the aircraft from unusual positions either in visual flight situations or during instrument training.

In a stall, the aircraft speed is reduced by raising the nose of the aircraft to the point where the aircraft is about to lose lift. As the wings stall, the nose of the aircraft drops fairly suddenly and the pilot has to increase speed by carrying out a diving maneouvre as he increases the power of the engine(s) whilst pulling out of the ensuing dive. This maneouvre tends to produce linear accelerations, particularly negative g, which stimulate the otolith organs and produce some visceral disturbance.

In a spinning maneouvre, the aircraft is stalled but one wing stalls before the other. The aircraft rolls over on its side and at the same time begins to rotate, the stalled wing moving backwards relative to the unstalled wing. This is a violently unstable rotary movement around the longitudinal axis of the aircraft in which there is a variety of linear and angular accelerations producing a complex stimulus to the vestibular apparatus. Likewise, during aerobatic flight, a wide variety of linear and/or angular accelerations may be experienced which stimulate both the otolith organs and the semicircular canals, depending upon the characteristics of the maneouvre. In addition to the inherent motion characteristics of aerobatic maneouvres, a student's lack of experience may well increase both the magnitude and variety of the vestibular stimuli produced, due to inexpert handling of the aircraft. The Coriolis or cross-coupled stimulation of vestibular receptors is aggravated if the occupant moves his head either voluntarily, in the performance of his flight task, or as an involuntary movement due to buffeting of the aircraft.

Whilst carrying out a recovery from an unusual attitude during instrument practice, the trainee pilot flies his aircraft entirely on the aircraft flight instruments and all external visual references are excluded by screening devices. The flying instructor places the aircraft in some unusual attitude before handing over control to the student who is required to recover from that attitude in the shortest time and with the minimum loss of height. Depending upon the aircraft attitude which has been selected, a variety of different vestibular stimuli may be experienced. There is also likely to be some degree of excitement or even anxiety associated with this type of procedure according to the level of experience of the student.

It has already been shown by many authors (Sjöberg, 1931; McNally and Stuart, 1942; Tyler and Bard, 1949), that stimulation of the vestibular apparatus is the underlying cause and indeed necessary for motion sickness. Benson (1973) summarized contemporary opinion:-

> 'These situations are characterised by the presence of a changing linear or angular acceleration and frequently both of these coexist. The accelerations differ in frequency, amplitude, duration or association from the types of stimuli which habitually accompany unassisted locomotion on earth. Thus the motion which is experienced in flight is unusual and unfamiliar. Sickness is not associated with all forms of unfamiliar motion, however. A more important facet of the motion which provokes sickness is the mismatch between information which is provided by the various sensory receptors which are stimulated (Lansberg, 1961; Guedry, 1965). It is the magnitude and duration of this sensory incongruity which is believed to be the principal determinant of the incidence of motion sickness (Reason, 1970).'

Nausea, but rarely vomiting, may also be precipitated by visual cues of motion which are unaccompanied by the appropriate physical stimuli (e.g. cinerama or fixed-base simulators with a moving T.V. display of an outside world).

The necessity of vestibular stimulation in the causation of motion sickness has

been shown by the observation that the condition does not appear in individuals who lack a functional vestibular apparatus. James (1882) reported that none of 15 deaf mutes who had been exposed to rough weather at sea had suffered from seasickness. Brown et al (1942) reported that 5 subjects whose labyrinths had been destroyed by meningitis were able to withstand 40 minutes on a pendulum-type swing without any sign or symptom of motion sickness. More recently Kennedy et al (1965) reported experiments in which 10 labyrinthine-defective subjects and 20 'normal' subjects, some of whom were highly resistant to motion sickness under various force environments, were exposed to extremely severe weather conditions at sea. None of the labyrinthine-defective subjects showed typical symptoms of motion sickness whereas 15 of the 20 'normal' subjects vomited and 5 experienced severe or moderate malaise. Secondly, in a 'normal individual' vestibular stimulation alone is sufficient to cause motion sickness provided there is an element of sensory mismatch. During rotation at constant angular velocity, if differing configurations of semicircular canals are brought into and out of the plane of rotation by rapid head movements, the Coriolis or cross-coupled stimulation of the canals is sufficient to cause motion sickness in most people. The intensity and duration of this type of stimulus which is required varies from individual to individual, but most 'normal' people can eventually be made motion sick by continuing this type of stimulus at a sufficiently high rotational speed (Miller and Graybiel, 1969 et seq).

This quantitative aspect of the stimulus which causes motion sickness gives rise to some of the difficulties in selecting a motion sickness susceptibility test. The more severe the test the more effective it is likely to be in identifying those individuals who will be troubled by motion sickness in flight but this is only achieved at the cost of rejecting many who would not be so affected, in other words the test wastage is high. The use of a milder test on the other hand allows a higher test success rate with a lower screening effectiveness. It is difficult to strike the correct balance.

The intensity and duration of stimulation necessary to provoke signs or symptoms of airsickness varies between individuals and for a given individual since most people can adapt to repeated exposure to vestibular stimulation. This is an important factor since aircrew may spend long periods of time off flying and lose their level of adaptation.

There is also some evidence in the literature that anxiety is a significant factor in the causation of airsickness though the evidence is conflicting (Money, 1970). For example Rubin (1942), who studied 837 trainee pilots suffering from airsickness at a primary Army Air Forces Flying Training Detachment, came to the conclusion that the most important causes of their airsickness were psychogenic in origin. The author (Dobie, 1970) has also found that psychogenic factors have an important part to play in causing airsickness and perhaps these are most prominent in individuals who have severe or intractable sickness. This aspect will be discussed more fully in the chapter which deals with treatment.

INCIDENCE OF AIRSICKNESS

It is clear from a survey of the literature that motion sickness is common and that the incidence varies widely according to the particular circumstances. Money (1970) in his review article referred to the incidence at sea varying from 1% to almost 100% depending on the type of vessel, the sea conditions and other variables. In terms of airsickness, Rubin (1942) quoted a figure of 11% for the incidence during basic flying training, ranging between 6% and 22% with different courses. Today's aircraft are vastly different and the flying programmes have changed to meet new requirements. The incidence and severity of airsickness during basic flying training will depend upon the type of student; the organization of the flying programme; aircraft type; weather conditions and other such fundamental variables.

When airsickness is intractable, student aircrew are removed from flying status; others who have failed flying training due to a lack of satisfactory progress in the air may also have some degree of airsickness as an underlying factor. Apart from those who are suspended from the programme a significant number of trainees, though able to complete their flying training, suffer airsickness to such an extent that their training syllabus has to be modified in order to minimize sickness during certain aerial maneouvres. The flying instructor may be forced to limit the number of aerobatic or spinning maneouvres on each flight to the detriment of training and when symptoms are severe the sortie may have to be abandoned prematurely.

The author investigated the incidence of airsickness amongst RAF trainee pilots whilst they were undergoing their flying training on single-engined jet aircraft (Jet Provost).

The information concerning the incidence and severity of airsickness during flying training was unsolicited, being obtained by reading the flying instructors' routine post-flight reports on 577 aircrew trainees. The severity of the condition was assessed from the instructors' comments concerning the decrement of performance which it caused during flight. As stated in the preface, this approach is considered to be more relevant than trying to measure the severity of the signs or symptoms of the malady since it more directly reflects the individual's disability in the flight environment.

The severity of airsickness was graded as 'mild' or 'severe'. 'Mild airsickness' denotes that the instructor recorded evidence of the condition but, in his view, it did not materially affect the student's ability to absorb instruction in flight. 'Severe airsickness', on the other hand, means that two or more sorties were abandoned prematurely or completely disrupted because of the performance decrement brought about by the student's airsickness. Frequently numerous other sorties had also been affected adversely.

The survey showed that 38.7% of pilot trainees suffered from airsickness at some time during their training, usually in the early stages, and in more than a third it was severe and protracted (Table 1).

These results show that airsickness wastes a significant amount of training time as measured by its adverse effects on an individual's ability to perform his task adequately in the air. The author was aware that by using instructors' training reports the figures relating both to the incidence and severity of airsickness could be conservative. Some students might have suffered from mild airsickness which was not obvious to the instructor and on occasion an instructor might forget to record a mild degree of airsickness. On the other hand, the merit of using this source of raw data lay in the fact that the economic penalty caused by the wastage of training time was readily apparent to executive authority.

NO RECORD OF AIRSICKNESS	MILD AIRSICKNESS	SEVERE AIRSICKNESS
61.3	24.1	14.6

Table 1.

Incidence of airsickness during pilot training based on instructors' records for 577 trainees (% incidence).

MILD AIRSICKNESS = Recorded evidence of airsickness which, in the view of the instructor, did not materially affect the student's ability to absorb instruction in flight.

SEVERE AIRSICKNESS = A degree of airsickness which was so severe as to cause a significant performance decrement. This resulted in a wastage of training time and also caused a number of sorties to be abandoned prematurely.

SOME FACTORS INFLUENCING THE INCIDENCE OF AIRSICKNESS IN FLYING TRAINING

The ability to predict susceptibility to airsickness is clearly a valuable attribute of any organization which is charged with the responsiblity of selecting aircrew trainees. The amount of training time and money which could be saved by an accurate assessment is highly significant. An obvious first line of attack on this problem is to investigate the relationship between an individual's relevant history at the time of selection for aircrew training with his manifest susceptibility to airsickness during flying training.

Information concerning previous flying experience and history of motion sickness was obtained from 1000 randomly selected aircrew students who were attending a ground training course which immediately preceded their basic flying training. The data concerning motion sickness were collected in the same form that was used at the Aircrew Selection Centre. This consisted of a simple question concerning an individual's history of "discomfort on swings, roundabouts, cars, aircraft and boats". On this occasion, however, an attempt was made to quantify the severity of that history as indicating 'mild' or 'severe' motion sickness. The qualification 'severe' signified that the individual had been susceptible to motion sickness for the greater part of his life; that it was related to most forms of travel and had produced a significant degree of incapacity. These answers were subsequently correlated with the individual's susceptiblity to airsickness during the basic stage of flying training, obtained by reading the flying instructor's routine post-flight reports.

In addition the incidence of motion sickness as indicated by these confidential questionnaires was compared with the responses to the same questions made by the candidates before they were accepted for aircrew training. This was considered to be an important part of the investigation; if relevant history could be shown to be a reliable means of predicting susceptibility to airsickness during training it was clearly essential to be able to obtain that information before a decision had been made to accept an individual for training.

Incidence and Severity of Airsickness during Flying Training Related to Previous Flying Experience

The relationship between the incidence and severity of airsickness during flying training and the amount and type of flying experience gained by 460 randomly selected student pilots prior to entry into the Royal Air Force is shown in Table 2. There is a positive correlation between the severity of the 'subsequent history of airsickness' during basic flying training and a lack of 'previous flying experience' before entry into the Royal Air Force, ($P < 0.01$ by chi-squared test).

There are two reasons which could account for this relationship. Firstly, many individuals who were severely airsick during civilian flying perhaps would not choose a career in aviation. Secondly, if an individual had a considerable amount of flying experience and particularly if it was continuous, he should have achieved a significant degree of adaptation to aircraft motion.

Although a positive correlation was found to exist between flying experience and resistance to airsickness, it can be seen from Table 2 that the exclusion from flying training of any individual who had no previous flying experience (PFE 0) is not a worthwhile selection criterion. In this series such a decision would only have excluded 7 individuals who were to become severely airsick (SHAS 2) and this would have been at the expense of 22 candidates who were not to experience significant airsickness during training (SHAS 0). It is also evident from Table 2 that amongst those with considerable previous flying experience (PFE 2) there was still a group of 21 individuals (out of the total of 159) who became severely airsick during their flying training (SHAS 2).

NUMBER OF SUBJECTS 460		SUBSEQUENT HISTORY OF AIRSICKNESS (SHAS) 0	1	2	TOTALS
PREVIOUS FLYING EXPERIENCE (PFE)	0	22	16	7	45
	1	98	55	40	193
	2	104	34	21	159
	UAS	46	15	2	63

Table 2.

Incidence and severity of airsickness during flying training (SHAS) related to flying experience (PFE) prior to entry into the Royal Air Force.

PFE 0 = No previous flying experience
PFE 1 = Less than 10 hours flying or passenger only
PFE 2 = 10 - 100 hours flying
PFE UAS = Ex-University Air Squadron student aircrew

SHAS 0 = No recorded evidence of airsickness
SHAS 1 = Evidence of mild airsickness
SHAS 2 = Evidence of incapacity due to airsickness

Finally it can be seen that the group consisting of ex-Unversity Air Squadron cadet pilots (PFE, UAS) had the lowest number of students who were severely airsick during training. This is partly because their flying training while at University was continuous and perhaps better organized than sporadic civilian flying. In addition they had been associated with flying for several years before deciding upon a career in aviation.

If the flying experience sub-groups were reduced in number from four to two by combining PFE(0 + 1) and PFE(2 + UAS) the association between lack of flying experience and subsequent airsickness susceptibility during training became more marked ($P < 0.001$, by chi-squared test). Nonetheless, the exclusion of the two least experienced groups at the initial aircrew selection stage would have been costly in manpower since a total of 238 candidates would have been excluded whereas only 47 (approximately 20%) were to become 'severely' airsick during training.

Incidence and Severity of Airsickness during Flying Training related to Previous History of Motion Sickness

The relationship between the incidence and severity of airsickness during flying training and the history of motion sickness prior to entry into the Royal Air Force of the same 460 randomly selected pilots is shown in Table 3. There is a positive correlation between the incidence and severity of airsickness during training and the pre-entry history of motion sickness, ($P < 0.001$ by chi-squared test).

NUMBER OF SUBJECTS 460		SUBSEQUENT HISTORY OF AIRSICKNESS (SHAS) 0	1	2	TOTALS
PREVIOUS HISTORY OF MOTION SICKNESS (PHMS)	0	127	42	10	179
	1	105	58	39	202
	2	38	20	21	79

Table 3.

Incidence and severity of airsickness during flying training (SHAS) related to history of motion sickness (PHMS) prior to entry into the Royal Air Force.

PHMS 0 = No previous history of motion sickness
PHMS 1 = Previous history of mild motion sickness
PHMS 2 = Previous history of severe motion sickness

SHAS 0 = No recorded evidence of airsickness during training
SHAS 1 = Evidence of mild airsickness during training
SHAS 2 = Evidence of incapacity due to airsickness

If all candidates who admitted to a history of severe motion sickness had been excluded at the Initial Selection Centre, this would have eliminated 21 individuals who would subsequently have been markedly airsick during training (SHAS 2). This procedure would also have excluded 38 other individuals who subsequently were not to show any tendency to airsickness during flying training. The candidates who apparently had never

suffered from any form of motion sickness (PHMS 0) were particularly resistant to airsickness, but to have accepted only that group at the Initial Selection Centre would have meant rejecting 281 candidates, or over 60% of the presenting population.

The relationship between previous flying experience and airsickness during training has already suggested that the ex-University Air Squadron population is apparently a select group. They were, therefore, excluded from the sample and the relationship between the previous history of motion sickness of the remaining 397 subjects and their airsickness susceptibility during training was examined. There was still a highly significant (P = 0.001) positive correlation between these two measures, but, as it can be seen from Table 4, this association does not constitute a useful selection criterion unless there is an abundance of candidates.

NUMBER OF SUBJECTS 397		SUBSEQUENT HISTORY OF AIRSICKNESS (SHAS) 0	1	2	TOTALS
PREVIOUS HISTORY OF MOTION SICKNESS (PHMS)	0	112	39	10	161
	1	87	53	38	178
	2	25	13	20	58

Table 4.

Incidence and severity of airsickness during flying training (SHAS) related to history of motion sickness (PHMS) prior to entry into the Royal Air Force (excluding ex-UAS candidates).

PHMS 0 = No previous history of motion sickness
PHMS 1 = Previous history of mild motion sickness
PHMS 2 = Previous history of severe motion sickness

SHAS 0 = No recorded evidence of airsickness during training
SHAS 1 = Evidence of mild airsickness during training
SHAS 2 = Evidence of incapacity due to airsickness

This part of the investigation showed the wastage of manpower which could occur if selection boards acted on the evidence of pre-acceptance flying experience and a history of motion sickness as predictors of motion sickness susceptibility during flying training. The importance of this wastage will vary with the abundance of candidates coming forward for selection and the number of aircrew required.

Comparison of Information on Previous History of Motion Sickness Given at Time of Selection with that Obtained by a Subsequent Confidential Questionnaire

In an attempt to assess the limitations of obtaining an accurate history from candidates during the selection procedure, 825 pre-entry medical questionnaires were examined. It was found that only 30 candidates (approximately 4%) had admitted to having suffered from any form of motion sickness before selection (Table 5, line 1). The second line of Table 5 shows that in response to the confidential questionnaire, 596 out of a total of 1000 aircrew trainees (approximately 60%) admitted that they had suffered from motion sickness prior to entry into the Royal Air Force and 162 of them stated that it had been severe. The majority of the 825 candidates whose medical documents were examined were included in the series of 1000. Under the circumstances, the figure of 4% is perhaps not surprising since these individuals were applying for a career in aviation and no doubt felt that they would not be accepted if they admitted to a history of motion sickness. Yet, when compared with the high number of affirmative responses to the confidential questionnaire it does highlight the difficulty of collecting accurate information on this subject at a time when it is useful, namely before a selection decision has to be made.

SOURCE OF INFORMATION	SAMPLE	AFFIRMED	%
MEDICAL FORM COMPLETED BEFORE ENTRY	825	30	3.6
CONFIDENTIAL QUESTIONNAIRE AFTER ENTRY	1000	596 (162)	59.6 (16.2)

Table 5.

History of motion sickness prior to entry into the Royal Air Force, recorded before and after acceptance for training. The figures in parenthesis refer to the number of candidates who admitted that their motion sickness had been particularly severe.

The use of sophisticated questionnaires should provide more reliable information and can be constructed so that veracity tests are included. For example, the validity of

a Pensacola motion sickness questionnaire has been reported by Hardacre and Kennedy (1965). The study was so designed that the motion sickness incidence recorded on a questionnaire was validated by subsequent data collected from other questionnaires presented to two similar groups of subjects. For each group, the questions were identical. On the first set of questionnaires, the confidential nature of the answers ('for research purposes only') was clearly annotated; in the second set the heading was omitted and in the third the annotation used on the first was pencilled out but readable. The fact that there was no significant difference between the results obtained from the three questionnaires was taken as an indication that the incoming flight students all responded with the same degree of veracity, regardless of the assurances they received. However, all the questionnaires were completed by students after they had been accepted for flying training in the United States Navy, so it was likely that the responses were more reliable because the candidates felt that having already been selected for training their answers were only of academic interest and were unlikely to influence their future career.

In conclusion, drawn from the investigations carried out on RAF student aircrew:

a) the evidence regarding past history of motion sickness, gained in confidence after acceptance for flying training, was very different from the incidence reported before acceptance;

b) even if apparently true evidence of an individual's previous flying experience and susceptibility to motion sickness can be obtained, there is a large economic penalty in terms of wastage of candidates at the pre-entry medical if these types of selection criteria are used.

The wastage of aircrew volunteers which would be caused by utilising this type of selection system casts grave doubts upon its efficacy. If meaningful selection criteria of airsickness susceptibility are to be found, some form of provocative test is required to supplement information about the candidate's previous history of motion sickness.

PROVOCATIVE TESTS FOR GRADING SUSCEPTIBILITY TO MOTION SICKNESS

Introduction

Certain provocative tests for grading the susceptibility of different individuals by means of their observed response to motion, under controlled conditions, seem to represent the most reliable approach to this problem. As far back as 1946 (Hemingway, 1946), it was found that in a group of subjects who had been withdrawn from aircrew training because of airsickness, 90.4% were sick on a swing test, whereas only 27.9% of aviators who did not suffer from airsickness were sick on the test. Although these results showed a positive correlation between 'airsickness' and 'swing sickness' the study highlighted a problem which typically occurs when a provocative test is used to assess susceptibility to airsickness. 9.6% of the subjects who were eliminated from flying training because of airsickness passed the test yet 27.9% of aviators who were not airsick failed.

Ambler and Guedry (1965) were able to show that if a vestibular stimulus, which over a long period would cause sickness, were applied briefly to aircrew trainees, the resulting severity of incipient motion sickness was a useful predictor of the likelihood of an individual completing his aircrew training. They also found, however, that to use this as a routine screening test would miss some airsick-susceptible subjects and fail others who would not have suffered from airsickness during training. This situation is parallel to that which was found by the author when relating flying experience and history of motion sickness to susceptibility to airsickness during basic flying training (Tables 2, 3 and 4).

Other Selection Tests

Numerous workers have described other tests of susceptibility to motion sickness a few of which will be described by way of example.

Johnson et al (1951) reported a significant correlation between individual susceptibility to motion sickness produced by a simple harmonic swing and the degree of concomitant head movement. They further found that the swing sickness could be almost totally overcome by preventing the subject from moving his head and thus eliminating gyroscopic movement.

Powell (1954) investigated subjects flexing their heads in a controlled manner whilst rotating at 16 rpm in a Barany chair. He found that there was a positive association between motion sickness susceptibility and the test reaction ($P < 0.001$).

Miller and Graybiel (1969) described a standard method for quantifying Coriolis sickness susceptibility in which subjects executed standard 90° head movements in the frontal and sagittal planes whilst seated in a chair rotating at one of several constant velocities. They found that the test velocity that evoked severe malaise within the set limits of 40 and 166 head movements could be predicted on the basis of the subjects' previous history of motion sickness. The same workers confirmed this work in 1970 and showed that the test provided stable results with a high test-retest reliability. It expressed quantitatively (in numbers of head movements) the likely susceptibility to motion sickness.

Clark and Stewart (1973) have reported on the relationship between motion sickness susceptibility and tests of perception of rotation in pilots and non-pilots. They stated that their data and several related studies suggest that there are wide individual differences in both susceptibility to motion sickness and vestibular response.

The fact that vestibular stimulation is clearly a prime factor in the causation of motion sickness led the author to investigate a test of vestibular sensitivity in seeking a means of assessing susceptibility to airsickness. The test which was chosen and investigated in detail was cupulometry, since it has been reported that most people who are susceptible to motion sickness have a cupulogram slope which is steeper than normal

(De Wit, 1953). This is also a very appealing test because it does not disturb the subject and the severity of the vestibular stimulus does not evoke sickness.

The author tested 1000 aircrew trainees by this method and related their cupulogram characteristics to flying experience, past history of motion sickness and susceptibility to airsickness during flying training.

Cupulometry

The technique of CUPULOMETRIA, or CUPULOMETRY as it is now more generally called, was developed by Van Egmond, Groen and Jongkees (1948) and the normal cupulogram was also described in that year by Hulk and Jongkees (1948). Cupulometry is a turning chair test which consists of measuring the duration of post-rotatory after-sensation evoked by a stopping stimulus. The duration of the sensation was thought to reflect the time taken for the cupula to return to its rest position following deflection by the deceleration. By use of a number of turn-table velocities the after-effects produced by various angular impulses may be determined and the appropriate stimulus-response graph, called a CUPULOGRAM, plotted. A schematic cupulogram is shown in Fig. 1. It is usual to plot the impulse on a logarithmic scale in order to achieve a straight-line relationship between the duration of after-sensation and the impulse. The gradient of this straight-line relationship (slope) was considered by Van Egmond, Groen and Jongkees to be a measure of the time constant of the exponential decay of the after-sensation and hence cupular restoration following deflection by the angular velocity step. Extrapolation of the cupulogram slope line to intercept the abscissa gives a measure of the impulse intensity at threshold. The originators of the test stressed the advantages of cupulometry over the classical Barany turning test as did others, (Aschan et al., 1952; De Wit, 1953). The main reasons for this were twofold. In the Barany test the duration of cupular deflection exceeded 'physiological limits'. More important still, the semi-circular canals were stimulated twice by the diametrically opposed forces of acceleration and deceleration which, although separated in time, were not sufficiently far apart for the effects of the acceleration stimulus to have worn off before the deceleration impulse took place. These difficulties were overcome by the design of the technique for cupulometry.

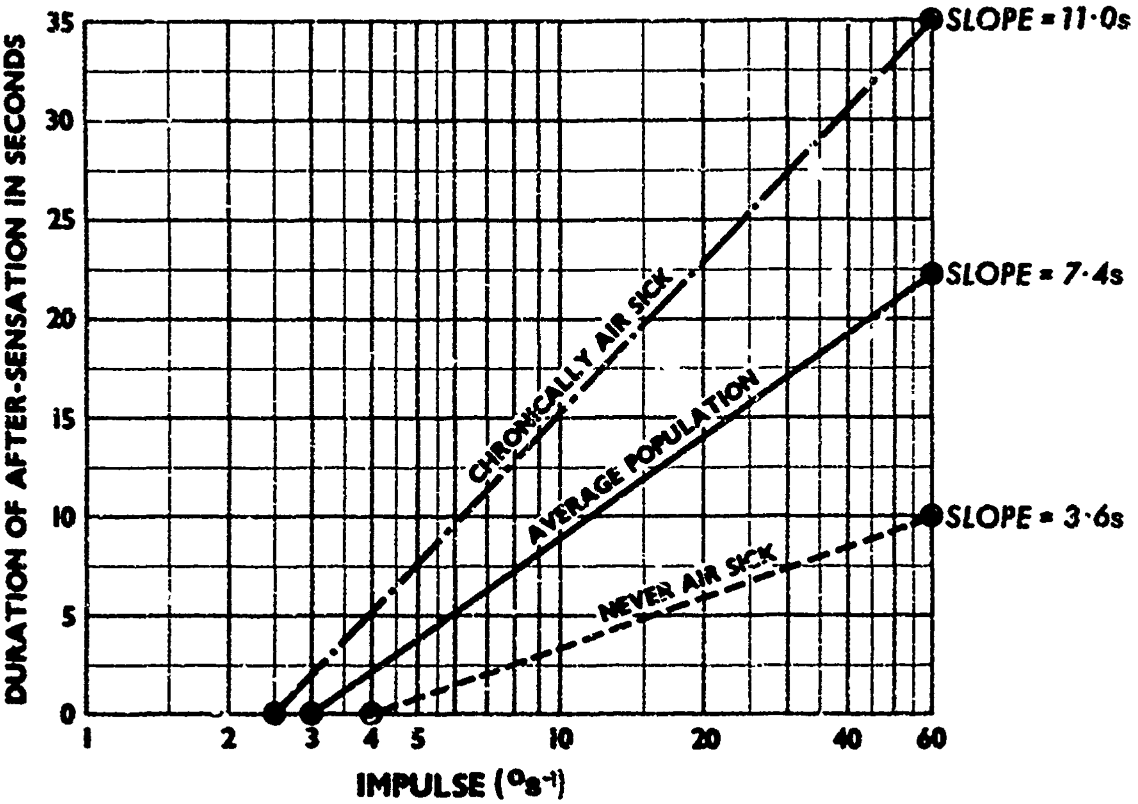

Fig. 1. Schematic Cupulogram

The Yaw Axis Sensation Cupulogram

The cupulogram establishes the stimulus - response relationship for rotational stimuli and as such provides a useful clinical measure of semicircular canal function. Slope and threshold values for the so-called 'normal' cupulogram were first published by Hulk and Jongkees (1948) based on data obtained from 50 subjects, most of whom were medical students. These workers found that the normal curve of the sensation cupulogram was generally a straight line with the following characteristics.

1. Slope: 'of the order of' 7s; range 5 to 16s.
2. Threshold: $2.5^{o}s^{-1}$ (average); range 0.75 to $5^{o}s^{-1}$.
3. The sensation cupulogram had a bend in 30% of the cases at 15 to $25^{o}s^{-1}$ and got steeper with increased magnitude of stimulus.

Various workers constructed cupulograms on a variety of different populations and their results are summarised in Table 6.

SOURCE	N	Mean Slope (S)	Mean Threshold ($^{o}s^{-1}$)
HULK & JONGKEES (1948)	50	7	2.5
ASCHAN et al (1952)	320	8.2	4.6
De WITT (1953)	22	9.0	3.0
ASCHAN (1954)	100	8.0	Not reported
BENSON et al (1966)	14	7.8	0.7
BENSON (1967)	142	6.8	1.4
DOBIE (1965)	158	7.2	1.4
DOBIE (see table 7)	1000	7.7	2.4

Table 6.

Summary of results from yaw axis sensation cupulogram studies by various authors.

Relationship Between Cupulogram Characteristics and Susceptibility to Airsickness

The main aim of the present investigation was not merely to seek a test of semi-circular canal function, however, but to evaluate the technique of cupulometry as a means of predicting susceptibility to airsickness.

De Wit (1953) used cupulometry as a possible means of identifying groups of subjects who had markedly different susceptibility to seasickness and compared their results with those of a control group. Thus there were 3 groups of subjects: the control group; a non-seasick group of sailors and a group of individuals who were particularly susceptible to seasickness. The cupulogram characteristics for these three groups of subjects were as follows:

S (control group)	mean slope	=	9s
	mean threshold	=	$3.0^{\circ}s^{-1}$
NSS (not seasick)	mean slope	=	4s
	mean threshold	=	$4.0^{\circ}s^{-1}$
ISS (seasick)	mean slope	=	13s
	mean threshold	=	$2.5^{\circ}s^{-1}$

Thus he demonstrated significant differences between the cupulogram characteristics of the chronically seasick group and the non-seasick seamen.

Later Aschan (1954) used the cupulometric test on groups of fighter pilots who had significantly different levels of current air experience. He was apparently able to show that fully trained fighter pilots who were in 'good trim' and flew most days had cupulograms which had a higher threshold value and a flatter slope than those of less experienced aviators. Other pilots who hardly flew at all could be identified with the non-aviator control group.

These apparent relationships between cupulogram characteristics and motion sickness susceptibility and different levels of flying experience encouraged the author to evaluate this technique in an aircrew population.

Plan of the Investigation

Cupulogram data were recorded from 1000 fit and healthy aircrew trainees prior to the beginning of their flying training. The turn-table (Fig. 2) which was used to carry out the investigation was built to the following specification:

(1) Velocity of turn-table could be controlled by the operator at rates of rotation between $3^{\circ}s^{-1}$ and $75^{\circ}s^{-1}$, to an accuracy of $\pm 0.5^{\circ}s^{-1}$; the maximum velocity used for cupulometry was $60^{\circ}s^{-1}$;
(2) Acceleration was smooth and pre-set at $0.3^{\circ}s^{-2}$;
(3) Deceleration was smooth and reproducible and did not exceed a stopping time of 1.5s;
(4) The turn-table cabin was light-proof, but well ventilated and insulated from directional external noises; it was also free from other than very minor sensations of vibration whilst rotating;
(5) The subject was provided with a headset and microphone so that he could communicate with the operator;
(6) The subject was seated so that his head was retained in a known, fixed position close to the axis of rotation.
(7) An extension of the box along the subject's line of sight contained an aircraft instrument dial 150 mm in diameter which was illuminated by an ultra-violet light source. This was used when the post-rotatory after-sensations were measured by means of the decay of an oculogyral illusion.

The test procedure consisted of eleven runs on a turn-table; the first was a training run at a speed of rotation of $45^{\circ}s^{-1}$ and the results of the other ten runs were

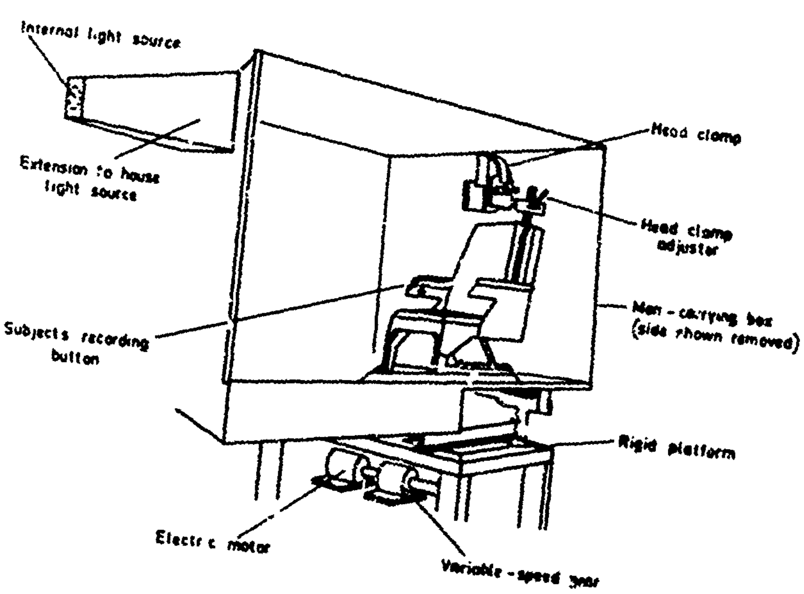

Fig. 2. Turn-table for Cupulometry. (The side of the man-carrying box has been removed to show the internal layout).

used to construct the cupulogram. The run speeds which were recorded were 60, 40, 20, 10 and $5^{o}s^{-1}$ and there was a run in each direction at these speeds. The order of the pairs of runs was always from the fastest to the slowest but the direction of the first run at each speed was randomised (forward/reverse/reverse/forward etc.). The turn-table was accelerated to the selected velocities at $0.3^{o}s^{-2}$ in order to minimize cupular deflection and the turn-table was then allowed to rotate for 1 minute to ensure that the cupula returned to its neutral position. The turn-table was then stopped abruptly and the subject experienced a sensation of turning. He was asked to indicate the end of this post-rotatory sensation by pressing a button. The operator recorded the duration of post-rotatory after-sensation for each run and these data were used to construct the cupulogram. The test was carried out with the subject in darkness or with the cabin instruments illuminated (oculogyral illusion end point).

Results

The mean slopes and thresholds of the cupulograms of the 1000 subjects in the whole series were 7.7s and $2.4^{o}s^{-1}$ respectively. These results are shown in Table 7, including a breakdown of the mean slopes and thresholds according to the type of subjective end point which was used by the subject. It can be seen that for both the mean 'threshold' and the 'slope', the values were lower for the subjects using an oculogyral illusion end point. However, in view of the range of numbers represented by these mean values the differences are not significant.

POPULATION MEAN SLOPE	7.7 s	(1000 SUBJECTS)
SUBJECTIVE SENSATION ENDPOINT	7.9 s	(327 SUBJECTS)
OCULOGYRAL ILLUSION ENDPOINT	7.7 s	(673 SUBJECTS)

POPULATION MEAN THRESHOLD	$2.4(^{o}s^{-1})$	(1000 SUBJECTS)
SUBJECTIVE SENSATION ENDPOINT	$3.0(^{o}s^{-1})$	(327 SUBJECTS)
OCULOGYRAL ILLUSION ENDPOINT	$2.2(^{o}s^{-1})$	(673 SUBJECTS)

Table 7.

Summary of population mean slope and threshold values of yaw axis sensation cupulograms. (1000 subjects)

The S.D. for the population mean slope was 3.1 and threshold 1.8. The SEM of the slope was 0.099 and threshold 0.056.

The total population of 1000 subjects was then broken down into sub-groups according to previous flying experience, previous history of motion sickness and subsequent history of airsickness during training. This information was gained from the confidential questionnaires which were completed by each subject immediately before undergoing cupulometry. The mean cupulogram characteristics of these sub-groups were then calculated and compared. The results are as follows:

(a) Effect of previous flying experience - The subjects were sub-divided according to the amount and type of their flying experience prior to undergoing cupulometry. It was convenient to divide the population into five sub-groups and these are defined in Table 8. The first three sub-groups are self-evident but the remaining two require further explanation. The subjects in sub-group PFE UAS were ex-University Air Squadron students who had some 200 hours flying experience in light aircraft, consisting of both dual and solo flying. The ex-University student aircrew were also in regular flying practice whereas those in the PFE 2 group had, in the majority, flown intermittently over a longer time. The relationships between the mean cupulogram characteristics and previous flying experience are shown in Table 8. There is no significant difference between the mean slope and threshold values in relation to flying experience.

TYPE OF SUBJECT	NUMBER OF SUBJECTS	SLOPE (s)	THRESHOLD ($^0s^{-1}$)
ALL TYPES	1000	7.7	2.4
PFE - O	110	7.7	2.4
PFE - 1	438	7.7	2.4
PFE - 2	318	7.8	2.3
PFE UAS	81	7.7	2.5
PFE - X	53	7.8	3.0

Table 8.

Mean slope and threshold values of yaw axis sensation cupulograms related to previous flying experience.

PFE 0 = No previous flying experience

PFE 1 = Less than ten hours flying or passenger only

PFE 2 = 10 - 100 hours flying

PFE UAS = Ex-University Air Squadron student aircrew

PFE X = Graduate aircrew

The S.D. for the slope within any group was 3.2 (mean; range 2.7-3.9) and threshold 1.8 (mean; range 1.7-2.0). The SEM of the slope within any group was 0.30 (mean; range 0.15-0.54) and threshold 0.16 (mean; range 0.08-0.28). Therefore, there were no significant differences either in the mean slopes or threshold values.

(b) Effect of previous history of motion sickness - the population was divided into three sub-groups according to the severity of the previous history of motion sickness. In keeping with the general approach adopted in this study, the severity was related to the degree of performance decrement which had been caused by motion sickness. These sub-groups are defined in Table 9 which also shows the mean cupulogram characteristics for each sub-group. There is no significant difference between the mean slope and threshold cupulogram values and previous history of motion sickness.

TYPE OF SUBJECT	NUMBER OF SUBJECTS	SLOPE (s)	THRESHOLD ($^{0}s^{-1}$)
ALL TYPES	1000	7.7	2.4
PHMS - 0	404	7.5	2.5
PHMS - 1	434	7.9	2.4
PHMS - 2	162	8.0	2.3

Table 9.

Mean slope and threshold values of yaw axis sensation cupulograms related to previous history of motion sickness.

PHMS 0 = No previous history of motion sickness

PHMS 1 = Previous history of mild motion sickness

PHMS 2 = Previous history of severe motion sickness

The S.D. for the slope within any group was 3.1 (mean; range 3.0-3.3) and threshold 1.8 (mean; range 1.7-1.9). The SEM of the slope within any group was 0.19 (mean; range 0.15-0.26) and threshold 0.11 (mean; range 0.09-0.15). Therefore there were no significant differences either in the mean slopes or threshold values.

(c) Effect of subsequent history of airsickness - These data were gathered from the flying instructors' post-flight reports and were thus entirely unsolicited. The population was sub-divided into three groups according to the degree of performance decrement produced by airsickness. The definitions of these sub-groups and the mean cupulogram characteristics are shown in Table 10. There is no significant difference in the mean slope and threshold values between the various sub-groups.

TYPE OF SUBJECTS	NO. OF SUBJECTS	SLOPE (s)	THRESHOLD ($^0s^{-1}$)
ALL TYPES	485	7.7	2.4
SHAS - 0	266	7.8	2.4
SHAS - 1	120	7.7	2.3
SHAS - 2	99	7.4	2.3

Table 10.

Mean slope and threshold values of yaw axis sensation cupulograms related to subsequent susceptibility to airsickness during flying training.

SHAS 0 = No recorded evidence of airsickness during training

SHAS 1 = Evidence of mild airsickness during training

SHAS 2 = Evidence of incapacity due to airsickness

The S.D. for the slope within any group was 2.88 (mean; range 2.86-2.90) and threshold 1.74 (mean; range 1.68-1.82). The SEM of the slope within any group was 0.24 (mean; range 0.18-0.29) and threshold 0.15 (mean; range 0.70-0.18). Therefore, there were no significant differences either in the mean slopes or threshold values.

The remarkable similarity of th slope and threshold values of cupulograms of groups of subjects of widely differing flying experience and proneness to motion sickness was very disappointing since it meant that cupulometry failed to provide an index of airsickness susceptibility.

This point is emphasised when further sub-groups which can be considered to be at the extreme ends of the spectrum are examined, namely, a group of student aircrew who were experiencing severe airsickness during training (SHAS 2) and a group of experienced flying instructors (PFE X) who were in current aerobatic practice. The relationship between the mean cupulogram characteristics of the two groups is shown in Table 11. Even in these circumstances the mean slope and threshold values were similar and did not significantly differentiate the sub-groups. Likewise Benson (1968) also failed to differentiate pilots suffering from airsickness from others by cupulometry.

Linear, as opposed to curvilinear cupulograms, were produced by 651 of the 1000 subjects. When the 349 curvilinear cupulograms were discarded and the mean slope and threshold values were recalculated there was little difference in the mean values which still failed to exhibit significant differences and hence to discriminate between the various sub-groups.

TYPE OF SUBJECT	NUMBER OF SUBJECTS	SLOPE (s)	THRESHOLD ($^0s^{-1}$)
SEVERE AIRSICKNESS DURING TRAINING (SHAS 2)	99	7.4	2.3
EXPERIENCED FLYING INSTRUCTORS (PFE X)	53	7.8	3.0

Table 11.

Comparison of mean slope and threshold values of yaw axis sensation cupulograms for group SHAS 2 (intractably airsick) and group PFE X (airsick-resistant).

The total after-sensation times were then calculated for each cupulogram and any directional preponderance was also measured by subtracting the total after-sensation time recorded in one direction from that in the opposite direction. The mean values of these measures were then calculated for the various sub-groups and the results are shown in Table 12. There was no significant difference between the mean values for the various sub-groups.

Discussion

In view of the failure of the technique to discriminate between groups of widely differing experience, the author concluded that the evoked response of the vestibular responses had a similar distribution in all subjects who were otologically fit. The major differences between cupulograms were an expression of the manner in which the different individuals assessed and reported their post-rotatory after-sensations. These were not necessarily independant of end-organ responses or the level of adaptation within the vestibular sensory system but no consistent relationship to the state of habituation to motion was found to exist.

Slope and threshold measurements of 1000 subjects who underwent cupulometry failed to show a significant relationship between flying experience, previous history of motion sickness and subsequent susceptibility to airsickness during flying training even in those aircrew where the cupulogram was shown to be linear. Similarly, directional preponderance and total after-sensation time did not show a significant relationship to susceptibility to airsickness in the population studied.

Although the author attempted to copy as closely as possible the significant features of the technique described by the original workers in the field of cupulometry, the results indicate that cupulometry cannot be used as a selection tool whereby large numbers of aircrew candidates can be screened routinely with a view to excluding those who are likely

to be troubled by airsickness during flying training.

Provocative tests may prove valuable in certain circumstances and should not be neglected completely. It is unlikely that any one single provocative test will be satisfactory and a battery of such tests may well be required. The results of these tests can then be assessed in the light of the student's background history of susceptibility to motion sickness at the time of selection for aircrew training. Nevertheless, the difficulty remains one of deciding upon where the cut-off in the test results should lie. An element of probability will undoubtedly always exist between test response and disability in the flight environment.

A

PFE	AFTER-SENSATION TIMES (s) MEAN VALUES	AFTER-SENSATION TIMES (s) RANGE	DIRECTIONAL PREPONDERANCE (s) MEAN VALUES	DIRECTIONAL PREPONDERANCE (s) RANGE	NUMBER OF VALUES
0	195.4	27.9-488.5	12.9	0-73.4	108
1	189.2	22.5-546.6	11.6	0-66.9	431
2	204.1	27.9-748.8	12.1	0.1-82.3	312
UAS	182.6	41.7-661.1	11.4	0.1-43.3	80
X	174.1	22.0-425.6	13.1	0.2-82.2	53
TOTAL	193.3	22.0-748.8	12.0	0-82.3	984

B

PHMS	AFTER-SENSATION TIMES (s) MEAN VALUES	AFTER-SENSATION TIMES (s) RANGE	DIRECTIONAL PREPONDERANCE (s) MEAN VALUES	DIRECTIONAL PREPONDERANCE (s) RANGE	NUMBER OF VALUES
0	184.4	22.5-546.6	11.4	0.1-79.0	397
1	193.9	22.0-579.7	12.4	0.1-82.3	428
2	213.8	41.7-748.8	12.4	0.1-61.1	159
TOTAL	193.3	22.0-748.8	12.0	0-82.3	984

C

SHAS	AFTER-SENSATION TIMES (s) MEAN VALUES	AFTER-SENSATION TIMES (s) RANGE	DIRECTIONAL PREPONDERANCE (s) MEAN VALUES	DIRECTIONAL PREPONDERANCE (s) RANGE	NUMBER OF VALUES
0	189.7	22.5-661.1	12.0	0.1-82.3	267
1	190.0	41.7-534.3	10.0	0.2-34.4	117
2	201.3	46.9-562.7	10.9	0.1-53.9	92
TOTAL	192.0	22.5-661.1	11.3	0.1-82.3	476

Table 12.

Mean post-rotatory after-sensation times and directional preponderance of different groups of yaw axis sensation cupulograms related to:

- **A Previous Flying Experience (PFE)**
- **B Previous History of Motion Sickness (PHMS)**
- **C Subsequent History of Airsickness (SHAS)**

PREVENTION OF AIRSICKNESS

Introduction

It has already been shown that airsickness is very common and that it wastes a considerable amount of valuable training time in the air. The clinical features of the malady are also very distressing for the sufferer and every effort should be made to minimize the effects of airsickness wherever possible.

The prevention of airsickness may be considered under 4 headings, namely,

(a) General measures

(b) The mitigation of specific precipitating factors

(c) Factors influencing habituation to motion

(d) The use of anti-motion sickness drugs

The employment of provocative tests for excluding those who are susceptible to motion sickness has already been dealt with and will not be considered under this heading.

General Measures

During their early flying experience, whether as student aircrew or passenger, many suffer from airsickness or worry about the possibility of it occurring. In this frame of mind they associate a whole variety of situations and apparent trigger mechanisms as causative factors of their airsickness. Education and reassurance can play a significant role in alleviating these fears and good management is equally important in getting an individual through his early experiences of flying without suffering from airsickness. Some of these factors will now be considered in terms of the individual and the flight situation.

(a) Individual factors

It is apparent from the author's clinical observations that anxiety is a very significant factor in the causation of airsickness. It may be due to fear of the unknown, if the individual has not flown before, or take the form of an overlay of anxiety in a person who has been exposed to disturbing motion stimuli before he has grown accustomed to them. The conditions of flight in modern jet transport aircraft are unlikely to provoke airsickness because these aircraft do not usually fly in turbulence for long periods of time. On the other hand, the fear of flying is likely to be a common cause of airsickness amongst passengers who have little flying experience and more prevalent than amongst those who have chosen flying as a career. It is important, therefore, to ensure that anxious passengers are reassured and diverted as much as possible. For example, music played over the aircraft public address system or through personal ear-tubes can go a long way to help such people relax.

The fear of motion sickness is also reflected in the widespread use which many people make of personal forms of protection. The apparent effectiveness of a chain dangling from a motor car is an example of one of these methods of preventing motion sickness. The confidence which is inherent in such a procedure can be sufficient to protect a certain type of person but he or she remains vulnerable, particularly in the absence of the appropriate 'charm'.

Student aircrew will have attended ground school for some time before they carry out their first flight in a training aircraft. Thus they can be reassured indirectly by a well orientated lecture programme which discusses the 'normality' of sensations of mild airsickness in the early stages of training, and emphasises the way aircrew overcome these symptoms with flying practice. In the event of a particular student being slow to adapt, then help and reassurance by his own flying instructor is of the utmost value.

Some student aircrew appear to find modern flying clothing uncomfortable and allege that this is a precipitating factor. In particular, many complain of the 'smell'

of a new oxygen mask or that their protective flying helmet gives them a headache and ultimately a feeling of nausea. This heightened awareness is a likely indicant of stress and these students should be encouraged to get used to wearing their flying equipment for lengthy periods on the ground; after checking that the fit is correct. The flying instructor can achieve this indirectly by encouraging his student to learn his cockpit layout and practise the various aircraft drills whilst fully kitted up and strapped into his aircraft seat.

The student's general state of health may be significant; the prodomal symptoms of some infections include nausea and this may present in flight. This is more likely to be associated with isolated instances of airsickness. Over-indulgence in alcohol during the previous evening can be a potent cause of airsickness on the following day. For this and obvious reasons of flight safety, parties should be discouraged when there is a flying programme scheduled for the next day.

Individuals who are prone to airsickness should avoid bulky greasy meals, particularly if there is little time to digest them before a flight begins. Feelings of nausea associated with food may predispose to an attack of sickness in the air.

(b) Factors associated with the flight situation

The design characteristics of particular aircraft can influence their response to turbulence and hence the degree of buffeting which is experienced by the crew and passengers. This basic problem can be further influenced by the position of the aircraft instruments used by the crew members, since the need to make head movements in a changing force field increases the intensity of conflicting vestibular signals. During World War II some troop-carrying aircraft were fitted with special head rests so that the passenger's head was restrained, thereby minimizing head movements and the resultant induced Coriolis vestibular accelerations, (Johnson and Mayne, 1953). The design of aircraft seats and in particular the seat harness is also significant. For example, the introduction of a crotch strap in certain harness systems, whereby the harness release box is secured in relation to the seat pan, prevents the user from rising out of his seat during exposure to vertical accelerations.

The adoption of a supine position reduces the likelihood of airsickness (Hall, 1942) and patients being evacuated by air who might suffer unnecessarily through vomiting should be encouraged to adopt this position and keep the head still during periods of flight in turbulence.

Many individuals are susceptible to foul odours and these may produce nausea even in the absence of significant vestibular stimuli. Similarly, the sight of another person vomiting can be disturbing and produce the same symptoms in the observer. Thus, good ventilation in the passenger or crew compartment, together with the discrete management of individuals who are being sick can improve the overall situation.

<u>The Mitigation of Specific Precipitating Factors</u>

Passengers who are known to be susceptible to airsickness or are showing signs of the malady should be located in the most stable part of the aircraft. This is usually a forward position or one located on the line of the wings.

When there are very inexperienced passengers or trainees on board an aircraft it is important to minimize motion stimuli by avoiding any violent unexpected maneouvres, since these people have not yet become accustomed to flying. Ideally, a new aviator's first few flights should be limited to air experience with gentle turns aimed at stimulating his interest in flying and allowing him to enjoy the new sensation of flight. During this time his level of habituation to vestibular stimuli will increase. It is undesirable to indulge in aerobatics even if they are requested, because for the reasons already given, the induction of motion sickness should be avoided at this stage of training.

In trainee aircrew who are known to be susceptible to airsickness it is important to boost their confidence by removing any fear of unexpected vestibular stimuli being imposed upon them by the addition of maneouvres which were not described during the pre-flight briefing. It is also valuable in such cases to make a point of carrying out the pre-planned aerobatic-type maneouvres towards the end of the sortie. Thereby the student knows that he will have no problems during the majority of the flight and that he will be landing shortly after the aerobatic sequence. This removes much of his worry should he feel sick during the period of aerobatics. This is not only good for his morale but also is a more productive training sequence.

It is usually a help if the airsick-prone individual can maintain visual orientation whenever possible. Strong reliable visual cues help to suppress conflicting cues from other sensory modalities.

Factors influencing Habituation to Motion

It is well known that in most people repeated or continued exposure to motion over a few days reduces their susceptibility to motion sickness. A state of habituation builds up in response to repeated vestibular stimulation (Guedry, 1965; Graybiel, Deane and Colehour, 1969) and equally well it is lost if the individual is not exposed to motion over a period of time which can vary from a few days to some 6 to 10 weeks. Thus, it is useful to increase a student's experience of aerobatic and spinning maneouvres gradually over successive trips and whenever possible to keep his state of habituation 'topped up' once it has been achieved. In many flying training courses there are phases when the student is programmed to carry out relatively 'straight and level' sequences, such as navigation exercises and these parts of the syllabus may be prolonged because of adverse weather conditions or periods of sickness or leave. This question of habituation should be borne in mind by all flying instructors and if the lay-off from flying has been particularly lengthy, it is worthwhile to curtail the student's exposure to violent maneouvres during his first trip on return to flying. It is also useful to include an occasional aerobatic maneouvre at the end of a navigational exercise if this is compatible with the efficiency of that training sortie. Thereby the student will be less likely to lose his level of habituation during that phase of training.

There is also evidence to suggest that ground 'vestibular exercises' have a part to play in helping individuals to achieve a state of habituation to motion and in maintaining that state, (Popov 1943). This can be achieved by means of gymnastic exercises which stimulate the vestibular apparatus, e.g. tumbling and rolling on a mat or by means of more sophisticated gymnastic equipment such as a trampoline. Repeated exposures to increasing Coriolis vestibular accelerations over a period of days have also been used successfully by the author, and others (Dowd, 1964), in the treatment of severe motion sickness. The author believes that the efficacy of this therapy is greatly enhanced when combined with a form of psychological deconditioning, as will be discussed later.

The Use of Anti-motion Sickness Drugs

The commonest approach to the amelioration of motion sickness, particularly amongst passengers, is the use of some form of medication. This can be one of many different anti-motion sickness drugs which are available, or even a placebo. The latter approach is more commonly used amongst trainee aircrew because medical officers are understandably cautious about the potential hazards associated with the unwanted effects of pharmacologically active drugs. The choice of drugs by passengers is very much the result of personal preference or the power of advertising. A physician, on the other hand, must balance the effectiveness of a particular compound and its unwanted effects against the needs and task of his patient, particularly if he is a member of aircrew.

Flying is both a skilled and potentially dangerous occupation so that any

decrement of performance brought about by medication can be very serious. For this reason, the use of an anti-motion sickness drug should be restricted to those situations where the patient is flying dual and therefore not in sole charge of the aircraft or responsible for a critical task. Nor should physicians prescribe medication to a particular member of aircrew for long periods, lest he becomes dependent upon it. This will make it increasingly difficult to withdraw the drug in order to effect a more acceptable and dependable 'cure'.

The situation is quite different with passengers. The unwanted effects of the drug of choice are much less serious and indeed a sedative action may be a positive advantage in such cases. Similarly, prolonged usage of drugs is less likely to occur because the flights are usually less frequent and fairly isolated in time. On the other hand, this means that passengers usually begin each trip in virtually an unhabituated state from the point of view of their susceptibility to motion sickness.

The efficacy of the most commonly used anti-motion sickness drugs have been evaluated on a number of occasions, (e.g. Chinn, 1956, Wood, 1964; Brand and Perry, 1966 and Wood and Graybiel, 1968 & 1970).

Chinn and his co-workers were concerned with the problem of protecting against motion sickness aboard transport ships and at that time decided that meclizine was the drug of choice for long sea voyages where it may be necessary to continue medication for several days. They came to this conclusion because it was one of the 3 most effective drugs, the other being cyclizine and promezathine, but its duration of action was longer. They did not recommend hyoscine in this situation because they found that relatively large doses and frequent administration were necessary (0.75 mg, three times daily) and this gave rise to distressing side-effects. Repeated administration is unlikely to be required in aviation, so as Chinn pointed out, hyoscine should not be precluded from the choice of drugs to be used against motion sickness of short duration.

Wood (1964) found that L-hyoscine, (scopolamine) 0.6 mg, still seemed to be one of the most effective drugs for preventing motion sickness. but pointed out that it had marked unwanted effects such as drowsiness, vertigo, dryness of the mouth and blurring of vision. Meclizine (50 mg) and cyclizine (50 mg) were reported to be the most effective of the antihistamines.

Brand and Perry (1966) reviewed the methods available for the study of drugs used in motion sickness and the information which had been derived from these methods. They concluded that there are 5 drugs whose value in the prevention of motion sickness was undisputed, namely, hyoscine, promezathine, cyclizine, meclozine and diphenhydramine. They were in no doubt that of these drugs L-hyoscine was, on a weight for weight basis, the most active, being about 60 times more potent than promezathine which is the most effective of the anti-histamines.

In 1968, Wood and Graybiel measured the relative effectiveness of a variety of drugs and combinations of drugs in a rotating environment by the number of "tolerated" head movements above or below the control (placebo) level. It was found that scopolamine (hyoscine) with its parasympatholytic action was the single most effective drug (dosage used 0.6 mg). Drowsiness and dryness of the mouth were prominent unwanted effects. Wood and Graybiel (1968, 1970) also studied the effect of a combination of sympathomimetic drugs and scopolamine; ephedrine and scopolamine acted in an additive manner,whereas amphetamine and scopolamine acted synergistically.

Wood and Graybiel (1970) re-evaluated certain anti-motion sickness drugs, including some new drugs and combinations of drugs and compared their effectiveness to prevent motion sickness under standardized conditions of stress in a slow rotation room. The results which were obtained are shown in Fig. 3. Of the single drugs used, they concluded that hyoscine (scopolamine) was the most useful and judged that a dose level

of 0.5 mg (as hyoscine hydrobromide) was optimal.

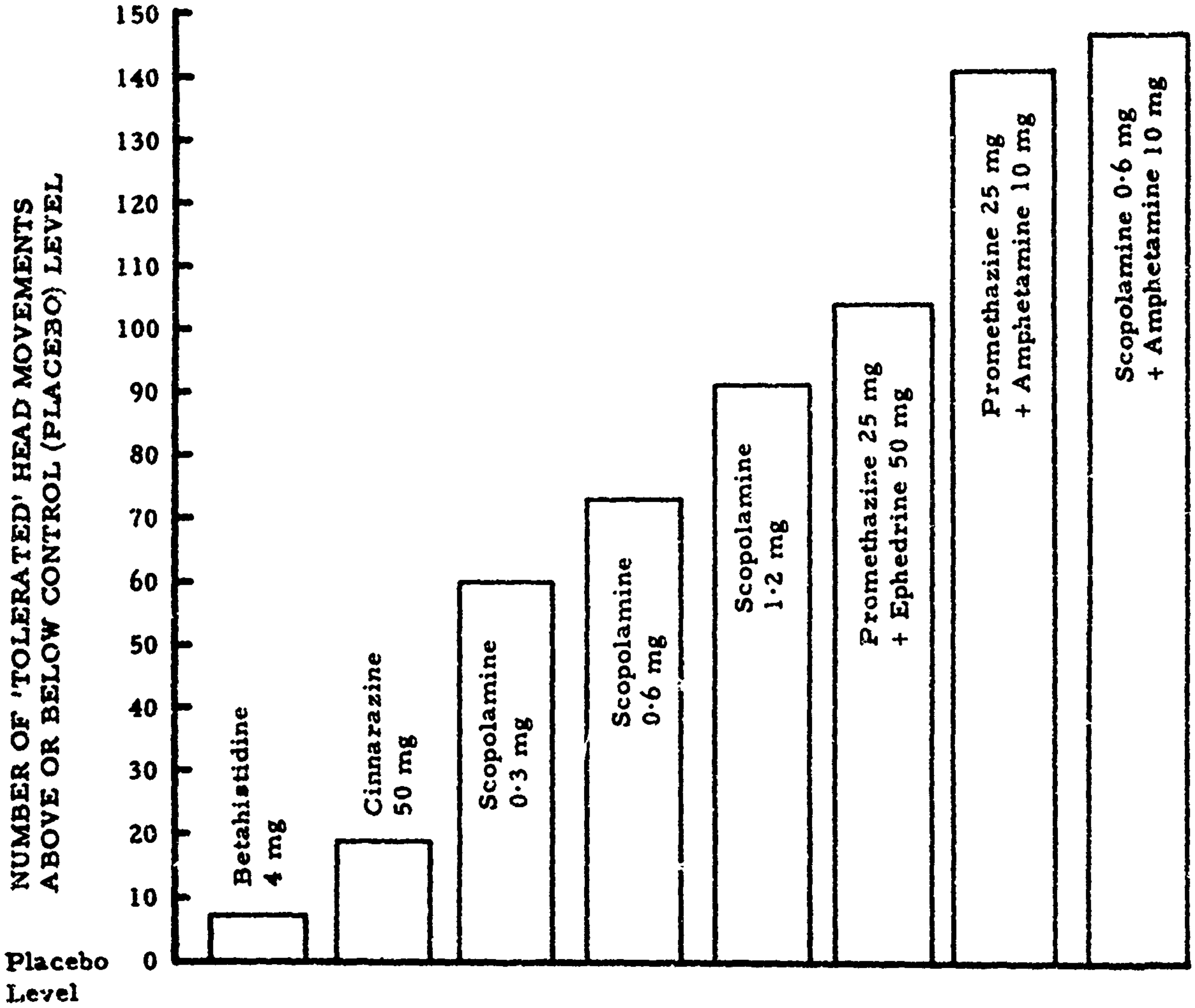

Fig. 3. Drugs and combinations of drugs ranked according to effectiveness (Wood and Graybiel, 1970).

The author carried out a crossed-over double-blind trial using 100 aircrew trainees, in order to investigate the unwanted effects of 0.5 mg hyoscine hydrobromide and 3 levels of dosage of Trimethobenzamide ('Tigan') which were included in the study (Dobie 1962, unpublished data). The results of the investigation are shown in Table 13. It will be noted that 5 subjects reported visual disturbances following the ingestion of hyoscine but none with either the placebo or with 'Tigan'. It is of particular interest to report that these visual disturbances were not specifically called for on the questionnaire (see Table 14) but all were reported under the heading 'any other disturbances'.

The majority of people who take effective anti-motion sickness drugs or combinations of drugs will experience unwanted effects to a greater or lesser extent. For this reason it is essential that their usage is strictly controlled by the physician in charge. It is then his responsibility to ensure that the patient does not exhibit personal idiosyncracies to the particular drug and that he is fully aware of the likelihood of unwanted effects.

TABLET CONTENT	INCIDENCE OF IMPORTANT UNWANTED EFFECTS			
	SLEEPINESS	DRYNESS OF MOUTH	DIZZINESS	VISUAL DISTURBANCE
HYOSCINE HYDROBROMIDE (0·5 mg)	40	46	18	5
'TIGAN' (100 mg)	17	10	4	NIL
'TIGAN' (200 mg)	15	2	1	NIL
'TIGAN' (300 mg)	20	11	1	NIL
PLACEBO	14	5	NIL	NIL

Table 13.

The incidence of important unwanted effects of certain anti-motion sickness drugs.

NAME ______________________

NUMBER ______________________ DATE ______________________

COURSE ______________________ TIME ______________________

Underline any of the following you have noticed:

1. Heartburn
2. Sleepiness
3. Dryness of mouth
4. Ringing in the ears
5. Feeling off colour
6. Tingling of the fingers
7. Nausea
8. Vomiting
9. Sneezing
10. Dizziness
11. Coldness of the feet
12. Headache
13. Give any other disturbances

Table 14.

Copy of the questionnaire used by the author in a trial to investigate the unwanted effects of certain anti-motion sickness drugs.

It is considered mandatory that all aviators, whether trained pilot or student, should be barred from taking these drugs when flying solo.

Management of Established Vomiting

Severe and repeated vomiting over a prolonged period of time can lead to marked dehydration and electrolyte imbalance. This is not likely to occur in the air but it could be a serious hazard for the aviator exposed to a survival situation at sea. The associated apathy and depression, which are common yet frequently neglected symptoms of motion sickness, can readily cause a severe decrement in performance with complete disinterest in whatever is going on around the sufferer.

The patient should be laid down, given fluids and reassured. Anti-motion sickness medication is useful but by this stage will probably not be retained if given orally. Brand and Whittingham (1970) have reported the value of intramuscular hyoscine hydrobromide (0.2 mg) in the control of motion sickness during sea survival. Heggie and Entwistle (1968) have found that a 50 mg dose of promezathine hydrochloride given intramuscularly is effective in the treatment of seasickness. Alternatively, the use of an anti-motion sickness drug in the form of a suppository would be advantageous in these circumstances. It is important for survivors who are at all likely to suffer from motion sickness that they take their oral medication as early as possible before they become too affected by the malady.

In summary, patients who are suffering from protracted vomiting due to motion should be encouraged to lie still with their eyes open and limit their head movements as much as possible, in order to minimize vestibular stimuli. They should be treated with one of the anti-motion sickness drugs which have been recommended, preferably by intramuscular injection. When they are markedly dehydrated it will be necessary to augment their fluid intake by intravenous infusion. If the patient has been vomiting for a long time he is likely to be in a state of metabolic alkalosis and his electrolyte deficit will require correction by the addition of suitable amounts of sodium chloride and potassium chloride to the infusion.

TREATMENT OF INTRACTABLE AIRSICKNESS

Introduction

The majority of people who suffer from airsickness when they first start flying either as trainee aircrew or passenger, soon get over it. They quickly adapt to the new environment within the first 15 hours or so of flying and their symptoms disappear. This time scale will vary with the breakdown of the flying programme since it will depend largely on the timing of the early aerobatic and spinning maneouvres. Other student aviators have a more prolonged history of airsickness and they will need some help and encouragement along the lines that have already been discussed in the previous chapter. Another smaller but very important group of people fail to respond to early treatment despite the efforts of their flying instructors and medical officer and gradually reach the stage where they can be classed as having 'intractable airsickness'. The decrement of performance in these students can be so severe as to critically affect their progress and their training supervisors have to decide whether or not it is justifiable to allow them to continue flying training.

'Intractable airsickness' represents a large economic loss to the flying training organization. Not only are these highly motivated and potentially valuable people on the verge of becoming training failures, they have already cost a large amount of money in terms of training hours and supervisors' time. For these reasons the author decided to investigate the possibility of treating such individuals so that they could, hopefully, return to flying training and eventually become useful, productive operational aircrew. As will be shown, this was not only achieved in a high proportion of cases, but it also became apparent that those who were recovered turned out to be above the average in terms of their ultimate standard of training.

Rationale of Treatment

In formulating a new approach to treatment for aircrew with intractable sickness the author considered the use of suitable medication, despite its apparent failure, but was biased against this approach for other reasons, namely:

a. Adverse unwanted effects associated with anti-motion sickness drugs frequently cause a decrement of performance in flight which could interfere with flight training. The restriction of the use of anti-motion sickness drugs to a 'dual flying only' situation is unsatisfactory because it introduces rigid flight programming factors.

b. There is a possibility that a drug could become a 'crutch' which, particularly in those with intractable airsickness, might create an additional problem when the drug was being withdrawn. In the author's experience, many individuals who had grown used to the protection of an anti-motion sickness drug were known to be apprehensive about flying without appropriate medication.

Treatment of Airsickness without the Use of Drugs

A student suffering from severe incapacitating airsickness inevitably shows some degree of anxiety or loss of confidence by the time he is referred for a second medical opinion. The psychological overlay seems inevitable because the student feels that his future career is in jeopardy. In others, the cause of 'sickness in the air' could be primarily psychological and entirely unrelated to motion, since nausea and vomiting are common reactions to stressful situations in certain types of personality, (Gellhorn and Loofbourrow, 1963).

The rationale of the treatment regime devised by the author is based on the principle of relieving the patient's state of anxiety whilst building up his level of acclimatization to vestibular stimuli by means of repeated head movements on a rotating platform. These movements produce a cross-coupled or Coriolis stimulation of the semicircular canals resulting in a sensation which is frequently bizarre and confusing and leads to the onset

of motion sickness if the stimulus is sufficiently severe and prolonged. The stimuli were carefully controlled to keep symptoms to the minimum. It was postulated that by so doing the main problems confronting the airsick-prone individual, namely lack of acclimatization to motion and an anxiety state, are treated in parallel. The candidate's improved performance on the turn-table, as manifest by his ability to withstand increasing amounts of vestibular stimulus over a period of time, also helps to increase his confidence and thereby lessen his anxiety overlay.

Method of the New Combined Psycho-physiological Approach to the Treatment of Intractable Airsickness:

Initial Interview

In all cases the management was similar; trainees with intractable airsickness were referred by a Unit Medical Officer when the local training organization had decided that the individual's progress in the air was critically affected. The patient came to the author's consulting room so that he was removed from his local environment as a first step. The main purpose of the initial consultation, which usually took about two hours, was to establish in the patient's mind the fact that airsickness during flying training is both common and 'normal'. The author believes that the ability of a patient to identify with normality is the first and most important step on his road to recovery.

The patient was asked to bring with him any information relevant to his flying and medical condition, including a detailed history of his airsickness. All these documents were left obviously unopened in front of the patient for the greater part of the initial interview. This was intended to convey to him that his physician was discussing airsickness in general and not a condition which was peculiar to the patient. By the end of this lengthy consultation all the problems which had beset the individual would hopefully have been covered in general terms with particular emphasis on the fact that airsickness is common amongst trainees and can be overcome. It was noticeable that throughout the consultation the patients became more talkative and showed other signs of becoming more relaxed. When all the various aspects of airsickness had been covered, the patient's personal documents were opened. Subsequent discussion then concentrated upon identifying the patient's particular problem areas with the previous general discussion and emphasised just how common these were in terms of the trainee population. At the same time, the medical history recorded by the Unit Medical Officer was checked and updated if necessary.

The course of treatment by means of a tilting turn-table was then described to the patient and he was asked if he wished to accept this form of therapy. At the same time he was reassured that this did not mean that he was committed to return to flying training unless he felt fit to do so in due course. It was emphasised that some patients suffering from 'sickness in the air' might simply be reacting to a dislike of service flying, either consciously or subconsciously. The patient was then asked if he had any second thoughts about continuing a career in military flying. At all times, the patient was taken through the various stages of treatment step by step; no further moves were made without his express consent and he was given the opportunity to opt out of flying at any time if he wished to do so. This approach was adopted during the early stages whilst the patient was anxious and under-confident so that he did not feel trapped into a long term arrangement before he could see a chance of success.

It is also considered to be particularly important that the physician does not become the patient's 'crutch' otherwise this form of treatment would be open to much of the criticism which has already been levelled at the pharmacological approach. The patient himself has therefore to say when he feels better and sufficiently confident to proceed to the next step. The author believes that it is essential that the patient's confidence does not stem from continual reassurance by the physician.

The first 50 unselected cases referred to the author all expressed a wish to be treated by means of vestibular exercises on a rotating/tilting table. Although all patients agreed to accept this form of therapy some did so with greater alacrity than others. During a subsequent review of the notes made during the initial consultations it became clear that those patients who were to fail subsequently despite treatment had shown less enthusiasm to proceed with treatment, though it would be dangerous to suggest that one could rely on such a deduction at such an early stage as a firm guide to selection. This observation can be taken into account at a later date, however, should doubts arise about the cost-effectiveness of continuing a lengthy course of treatment for a particular patient.

Commonly, the patients began their turn-table treatment within a few days of the initial interview. Only in two cases did a period of weeks intervene and that was due to programming difficulties at the patients' own unit.

Rotating/Tilting Table:

The main feature of the treatment turn-table was that the patient's chair could be tilted through 90° in the fore and aft and lateral planes or any combination of these two maneouvres at the same time. Photographs of this seat and examples of the various tilt positions can be seen in Figs. 4 & 5.

The rotation of the turn-table and the tilting of the chair were both controlled remotely from the operator's control panel which was equipped with digital counters for recording the number of tilt maneouvres performed in particular directions. This information was recorded as part of the treatment programme. Details of the equipment are as follows:-

a) Man-carrying box - The box was built on a turn-table platform and was constructed with a metal skin and insulated to cut ambient noise levels to a minimum, and minimize external noise sources which could provide rotational cues. One side of the box could be removed entirely for servicing but routine access was gained by a door located in the removable side.

b) Electromechanical turn-table equipment - Rotation of the platform was controlled by means of a remote 'forward/stop/reverse' push button located on the operator's control panel. The acceleration of the turn-table was smooth and maintained at a fixed level of $0.3^{\circ}s^{-2}$. Deceleration was achieved by an electro-hydraulic disc brake which could stop the turn-table in a reproducible manner in $1.5 \pm 0.2s$, if required for a provocative test such as cupulometry.

   A set of electro-mechanical actuators could tilt the subject's chair through 90° in the fore and aft plane and a second set controlled its positon within an arc of 90° in the lateral plane. These movements could be carried out separately or together, thus permitting a number of tilt patterns whilst the turn-table was rotating. These maneouvres are described in detail under the heading, 'Plan of the turn-table programme'.

c) Operator's Control Panel - The complete operation of the turn-table was controlled from this position by the operator and the panel also housed all the indicator and timing equipment. The acceleration of the turn-table was pre-set, but the operator controlled the velocity for each run to an accuracy of $\pm 0.5^{\circ}s^{-1}$ by reference to a tachometer indicator (calibrated from 0 to $75^{\circ}s^{-1}$) located centrally on the panel. The operator stopped the acceleration when the desired run speed was reached. The system was also fitted with a velocity limit of $70^{\circ}s^{-1}$ as a safety measure. The controls for tilting the patient's chair and the digital counters which recorded the number and type of tilting maneouvres were located on the control panel.

d) Subject's Seat - The subject entered the box through a door located in the removable side of the box. His chair, which could be tilted through 90° in the fore and aft

plane was suspended in a rectangular metal frame which could be tilted through 90° in the lateral plane. An upward extension at the back of the seat terminated in an adjustable head clamping device. This, together with an aircrew oxygen mask attached to the head rest, ensured that the subject's head was restrained in a known position. The subject was provided with a hand-held switch which he operated if he wished to abandon a treatment run for any reason, (see Fig. 4).

Fig. 4. A subject in position for a treatment run. His head is restrained in a padded head-rest. The button which he is holding can be used to abandon a treatment run if his symptoms of motion sickness become severe. A pair of actuators which tilt the seat can be seen in the foreground.

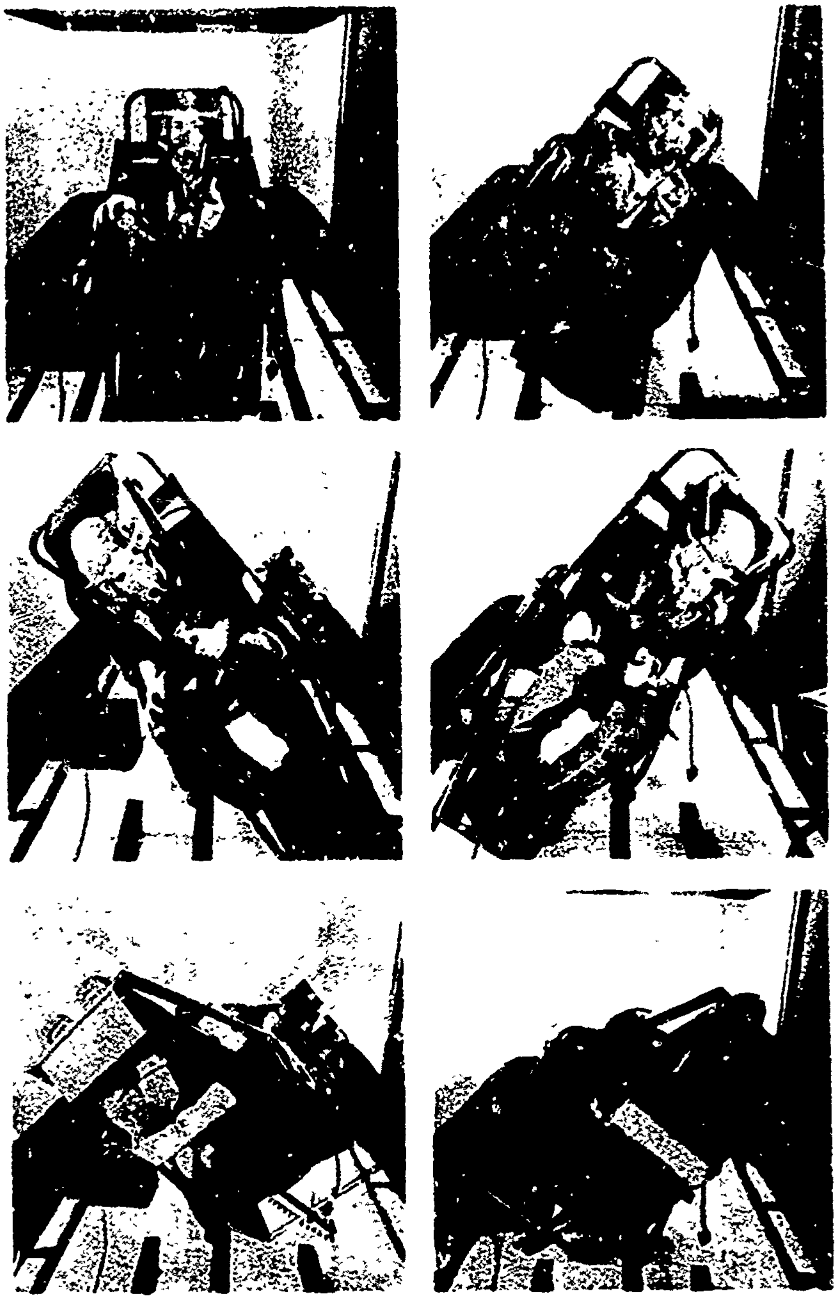

Fig. 5. A series of views of various tilt positions which can be selected during a treatment run.

Plan of the Turn-table Programme

The severity of the vestibular stimulus which can be imposed by this type of equipment depends upon three variables, namely the speed of the rotating platform, the pattern of the tilting maneouvres and the number of these maneouvres which are carried out during a single treatment session. The aim of the exposure to various motion patterns was to increase an individual's level of adaptation to vestibular Coriolis acceleration without producing an uncomfortable degree of motion sickness. It was considered to be important to limit the severity of exposure since the main objective of the treatment was to increase confidence; a severe bout of motion sickness during a run could well have the reverse effect. The various patterns of maneouvres which could be performed on the turn-table are shown diagrammatically in Fig. 6. Initially

a 'square' pattern of subject movement was employed because it provided a mild vestibular stimulus. Later, random movements were used throughout.

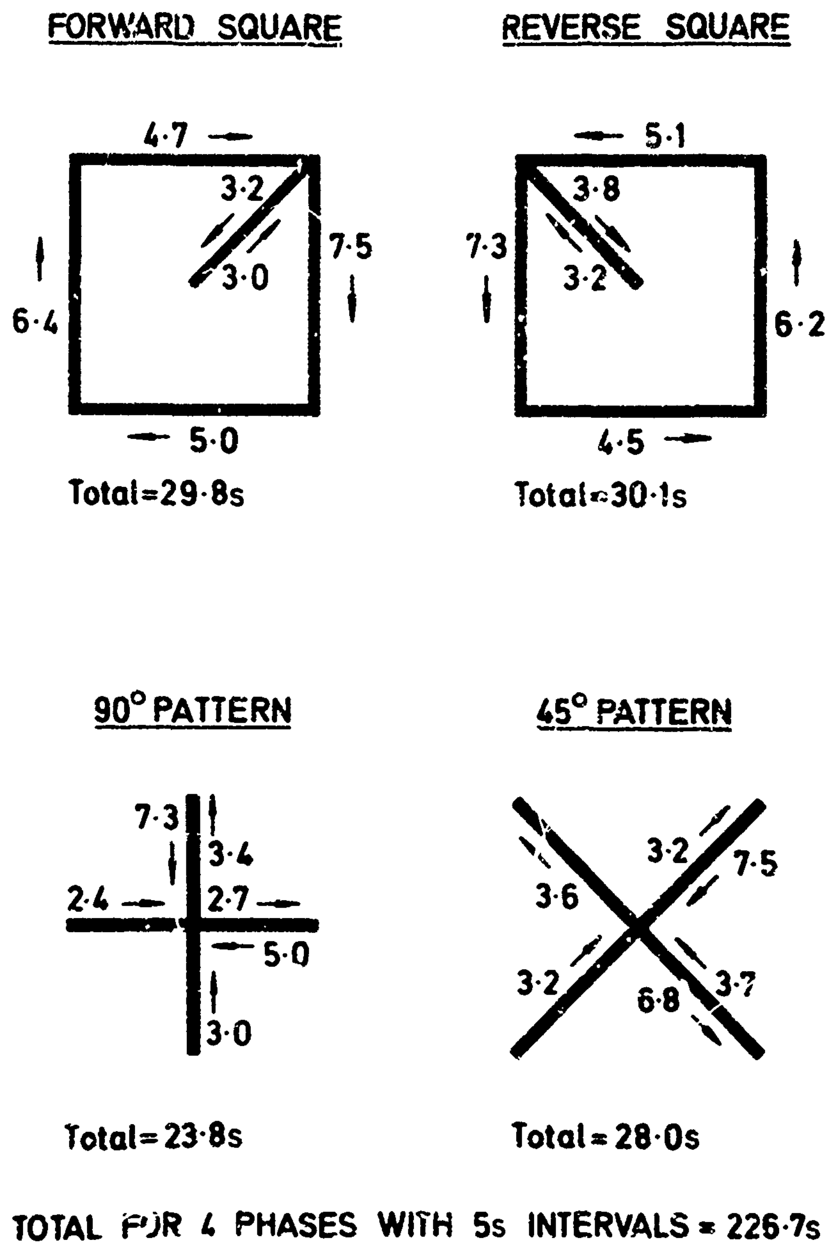

Fig. 6. Diagrammatic representation of the various tilt positions as seen from above. Completion of the various movements in one pattern is referred to as a 'phase' in the summarised treatment patterns in the case histories.

In order to ensure that a subject did not experience symptoms of motion sickness during the earliest runs, he was limited to four tilts at a rate of rotation of $30^{\circ}s^{-1}$. The patient had previously been informed that this was not a 'trial of strength' and that he could abandon a run at any time, either on request or by pressing the button which was provided for that purpose. At no time did any patient vomit whilst undergoing treatment on the turn-table. On completing a run, the subject was questioned and examined for symptoms or signs of motion sickness.

Each patient was given two runs per day but the second run was cancelled if he had

any evidence of motion sickness remaining from the previous exposure. The vestibular training pattern and magnitude of vestibular stimulus on a given run were then adjusted according to the severity of symptoms produced by the previous run. The programme of training was aimed at increasing the exposure to vestibular Coriolis acceleration as much as possible without producing an unacceptable degree of motion sickness.

Patients were required to maintain a personal record of their pattern of treatment in graphical form. This evidence was intended to emphasise his ability to withstand progressively stronger stimuli without experiencing a significant increase in symptoms of motion sickness.

The duration of the turn-table treatment programme was left open-ended since the author could not predict the response of each subject to this type of treatment. Although there was no critical end point in terms of a particular stimulus intensity, the aim was to achieve a state of adaptation whereby the patient could sustain random tilt patterns at a speed of rotation of $60^{o}s^{-1}$ without significant discomfort from the vestibular stimuli.

At some time during the treatment programme, the author discussed progress with the patient. This took place either when an individual seemed unable to cope with an increased Coriolis stimulus after a number of exposures at a particular level, or after a week of treatment if no problems had arisen. During this consultation the patient was expected to discuss his progress with the help of his treatment chart. This reinforced his confidence because it provided him with evidence that he was capable of adapting to increased levels of Coriolis vestibular acceleration.

When a satisfactory state of training had been reached, the patient was seen once more and his treatment schedule was discussed finally. In successful cases, the vestibular training lasted on average about two weeks. At this stage the patient was asked if he was ready to return to flying training. If he expressed confidence and willingness to get back to flying, arrangements were made for him to do so straight away so that he did not lose the adaptation which he had gained on the turn-table. In order to bridge the gap between the acclimatization achieved on the turn-table and the training aircraft, the first flights were controlled by a medical officer flying instructor. During these flights the patient progressed in a prescribed fashion from dual flying with minimal vestibular stimuli to solo unrestricted aerobatic flight, (see appendix). On reaching that point successfully the patient returned to routine flying training at his usual Training School.

There was no formal follow-up procedure planned at that stage. This fact was made known to the patient and was intended to boost his morale and to emphasise that the physician was confident that he was now capable of returning to routine unrestricted flying training.

The follow-up information which is discussed in the results section was obtained by writing to all the ex-patients some 4 years after their return to flying. In those candidates who failed, the cause was obtained from executive records.

Patterns of Treatment on the Rotating/Tilting Table

The aim of the treatment programme was to expose a patient to progressive increments in vestibular Coriolis acceleration, consistent with his level of adaptation, so that he only experienced mild symptoms of motion sickness. It was essential that this threshold was not exceeded otherwise the patient became anxious and despondent. Frequently there was a latent period between the end of a treatment run and the onset of symptoms, and in some the severity of symptoms increased after a run was completed. For these reasons, the supervisor had to exercise great caution in selecting the stimulus sequence. Accordingly, patterns of treatment differed for each patient, each run on the rotating/tilting table being tailored to an individual according to his progress and level of adaptation.

10 Examples of Different Responses to Treatment

The following 10 examples of different patterns of treatment on the turn-table and the subsequent outcome of that treatment have been chosen to illustrate the responses of different types of patients in the series of fifty consecutive unselected cases of airsickness treated by this new technique. The case histories of these 10 patients are summarised in Case Reports 1 - 10, and their respective treatment patterns are described.

For convenience the individual patterns of treatment of these 10 cases are also displayed together in Fig. 7 for purposes of comparison. This demonstrates clearly the wide variations both in the total number of runs, ranging from 16 in the case of subject CDC to 65 in the case of subject DMI, and the type of stimulus employed at the various run speeds. In the diagrammatic representations of treatment, the figures above the columns denote the number of phases (completed patterns) at a particular speed of rotation.

Subjects RM and PLAM (case reports 1 & 2) were both student pilots from a Basic Flying Training School who were subsequently returned successfully to complete their training. They were both treated in the early part of this programme, so they started with 'square' tilt patterns on the turn-table. The reduction in the speed of the turn-table platform at the beginning of the '$90^{\circ}/45^{\circ}$' sequences was deliberate. In the case of PLAM (Fig. 9) the rate of rotation of the turn-table was reduced to $30^{\circ}s^{-1}$ to ensure that the new pattern did not produce symptoms; this adjustment had been made because RM (Fig. 8) had been forced to abandon his first 'diagonal' pattern at $45^{\circ}s^{-1}$ having found the new type of stimulus too severe at that speed of rotation.

These patterns of treatment were similar, but PLAM's was prolonged mainly due to the 3 extended exposures, around the 8th, 18th and 25th runs. He required these additional runs to adapt to that level of stimulus. Both subjects have since become successful operational pilots, RM in bomber aircraft (Vulcan) and PLAM in fighters (Phantom).

JST and AEW (case reports 3 & 4) were also student pilots from a Basic Flying Training School but they were treated later in the series when the treatment pattern began with 'random' movements. In both individuals, 'square' patterns were introduced into the programme to reduce the level of stimulus when they were slow to adapt to a particular rate of rotation. AEW (Fig. 11) spent more time on 'square' patterns than JST (Fig. 10) but they both completed their programmes satisfactorily in 44 runs on the turn-table.

These courses of treatment lasted much longer than in either of the previous patients. It is unlikely that this was due to the use of 'random' movements. JST experienced nausea on the first run but AEW was entirely symptom-free for the first 3 runs. It seems more likely that JST and AEW were slower to adapt to Coriolis stimulus than were the previous patients RM and PLAM. It is also interesting to note that both JST and AEW received their advanced training on the twin piston-engined Varsity aircraft, and both finished up flying Hercules aircraft, whereas the other two patients proceeded through training in the high-performance stream. In a letter to the author some years after he finished training JST stated:

> "I nominated to go onto the Varsity and Hercules partly, originally, with my previous record in mind and I have no doubt now as to my choice. I think, possibly that if I had gone onto the faster, more maneouverable type of aircraft, such as the Gnat, then my airsickness would have returned."

JST has had no episodes of airsickness at any time during 150 hours on the Hercules tactical transport although he has been exposed to turbulence in different types of weather and whilst flying at low level.

AEW applied for advanced training on the Gnat but happened to be chosen for the

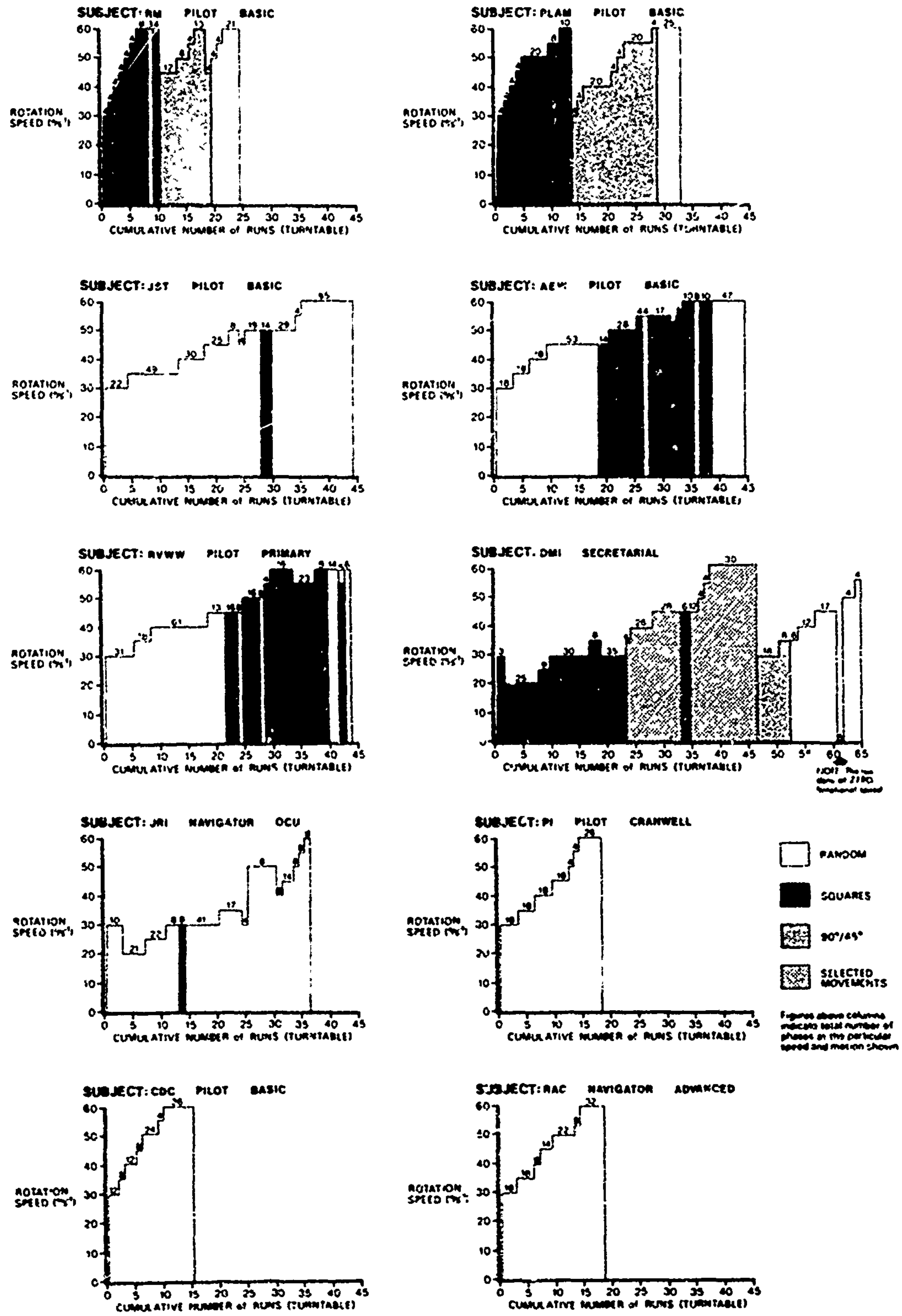

Fig. 7. 10 examples of different responses to treatment. The figures above the 'columns' represent the total number of phases (or completed patterns) at a particular speed of rotation.

CASE REPORT No. 1

Subject: RM

Pre-entry Flying Experience: Gliding: dual launches - 40
solo launches - 20
Powered flight: Chipmunk - 12 hrs. dual
Auster 18.30 hrs. dual
11.30 hrs. solo
Passenger 35 hrs.

Date of last flight: more than a year ago

CODE: PFE 2

Pre-entry History of Motion Sickness: Airsickness - nil
Seasickness - twice on channel ferry in 'normal' seas
Vehicle sickness - nil
Swings/roundabouts etc. - nil

CODE: PHMS 1

Cupulogram Characteristics on Entry: Slope 8.8s
Threshold $2.2^{o}s^{-1}$

Airsickness during Flying Training: Numerous episodes of airsickness during early part of basic training on Jet Provost aircraft. Sufficiently severe to cause a number of sorties to be abandoned or materially altered to the detriment of training (CODE: SHAS 2).

Despite the medication (hyoscine hydrobromide 0.5 mg), RM continued to be airsick, particularly during aerobatic maneouvres, until he was withdrawn from training. By that time he had made little progress in flight because of his airsickness.

Course of Treatment: RM underwent a course of treatment on the turn-table which is described in detail in Fig. 8.

Rehabilitation Flying: 12 sorties under the supervision of a medical qualified flying instructor. These followed the general pattern laid down in the appendix.

Follow-up: Completed basic training successfully (Jet Provost a/c) 50 hrs.
Completed advanced training successfully (VARSITY a/c) 100 hrs.
Operational conversion unit & squadron (VULCAN BOMBER) 800 hrs.

No airsickness since treatment.

TREATMENT PATTERN

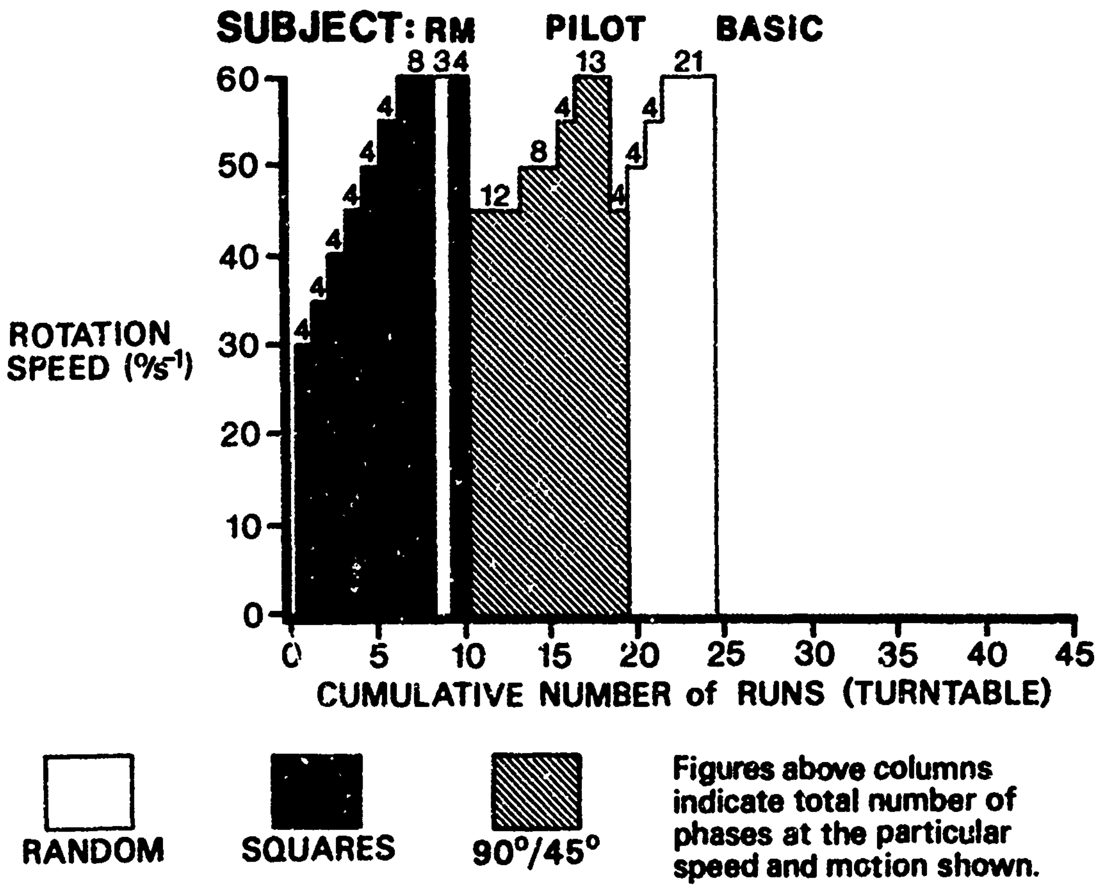

Fig. 8

SUMMARY OF TREATMENT: Subject RM.

Turn-table:	Number of runs	24
	Total number of phases	109
	Average number of phases per day	7.8

Symptoms during Runs:

Symptom	Number of Runs
Nausea	19 (began on 3rd run)
Dizziness	1
Confusion	4
Sweating	4 (began on 2nd run)
Abort	1 (during 1st diagonals 90°/45°)

CASE REPORT No. 2

Subject: PLAM

Pre-entry Flying Experience: Powered flight: Passenger 20 hrs

Date of last flight: 9 months ago

CODE: PFE 1

Pre-entry History of Motion Sickness: Airsickness - nil

Seasickness - slight, once

Vehicle sickness - as a child

Swings/roundabouts etc. - nil

CODE: PHMS 1

Cupulogram Characteristics on Entry: Slope 7.9s

Threshold $3.1^{o}s^{-1}$

Airsickness during Flying Training: Numerous episodes of airsickness during Chipmunk and Jet Provost training, resulting in the abandonment of numerous sorties and an adverse effect on training (CODE: SRAS 2).

Despite medication (hyoscine hydrobromide 1/200 gr), airsickness became progressively worse until he was withdrawn from flying training.

Course of Treatment: PLAM underwent a course of treatment on the turn-table which is summarised in Fig. 9.

Rehabilitation Flying: 16 sorties under the supervision of a medi [illegible] flying instructor as laid down in the appendix.

Follow-up: Completed basic training successfully (Jet Provost a/c).
(Won Sword of Merit: Flying Prize: 2nd in Aerobatic comp.
Completed advanced training successfully (Gnat a/c) 100 hrs
(Won Flying Prize and 3rd in Aerobatic competition)
Operational conversion and squadron (Hunter Fighter) (Phantom Fighter) 600 hrs

Only occasional airsickness when stressed (e.g. conversion to new type of aircraft).

TREATMENT PATTERN

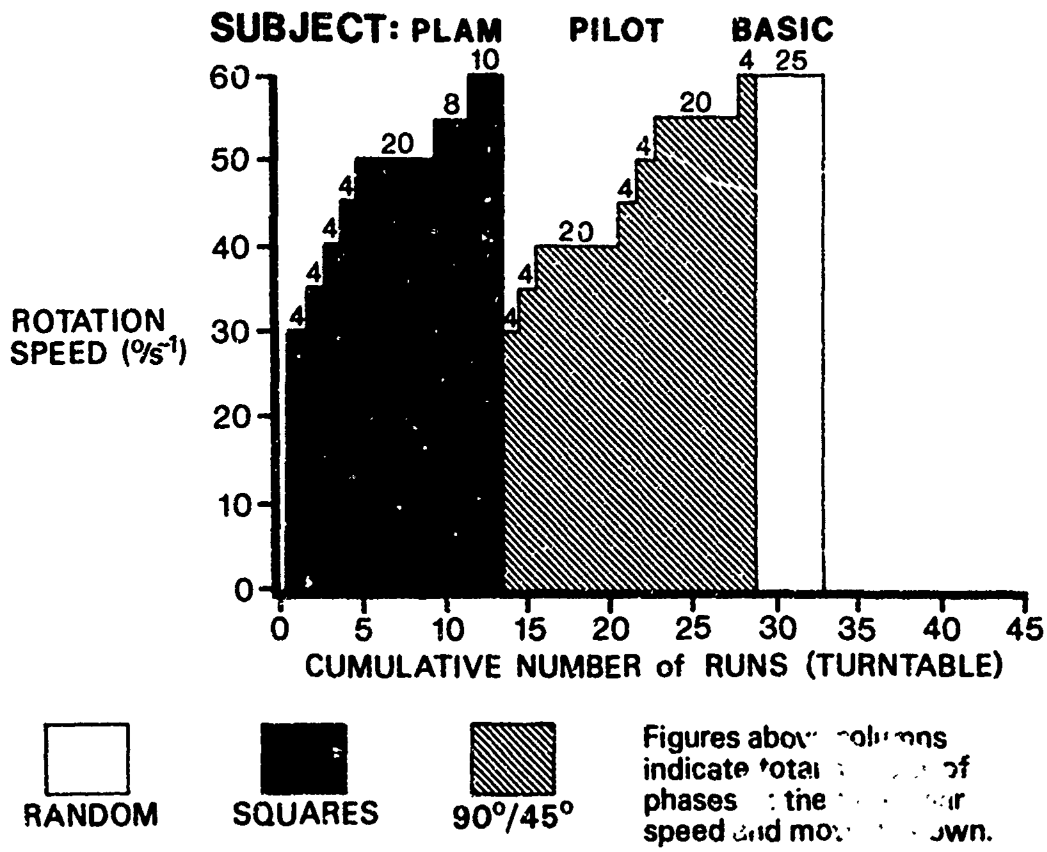

Fig. 9

SUMMARY OF TREATMENT: Subject PLAM

Turn-table:	Number of runs	32
	Total number of phases	139
	Average number of phases per day	9.3

Symptoms during Runs:

Symptom	Number of Runs
Nausea	7 (began on 6th run)
Dizziness	24) (began on 3rd run)
Confusion	3)
Sweating	15 (began on 2nd run)
Abort	nil

CASE REPORT No. 3

Subject: JST

Pre-entry Flying Experience:	Powered flight: Auster 30 hours (Passenger)
	Date of last flight: Over 1 year ago
	CODE: PFE 1
Pre-entry History of Motion Sickness:	Airsickness - nil (no experience of spinning or aerobatics)
	Seasickness - mild: up to age of 10 yrs
	Vehicle sickness - buses: up to age of 10 yrs
	Swings etc. - nil
	CODE: PHMS 1
Cupulogram Characteristics on Entry:	Slope 7.4s
	Threshold $2.8^{o}s^{-1}$

Airsickness during Flying Training: Numerous episodes of airsickness during general handling sorties beginning with the first trip which was devoid of aerobatic type maneouvres. After 10 weeks he was given 0.3 mg tablets of hyoscine hydrobromide for use before each dual trip. The medication was ineffective and he was withdrawn from flying training. (55 hrs JP flying). He was nauseated and unwell on 6 trips and vomited on a further 4 sorties. On all these occasions the effects of airsickness interfered with training efficiency. (CODE: SHAS 2)

Course of Treatment: Treated on turn-table (see summary in this case report). Fig. 10.

Rehabilitation Flying: 14 sorties under the supervision of a medical qualified flying instructor as laid down in the appendix.

Follow-up: Completed basic training successfully (Jet Provost a/c) 120 hrs
Completed advanced training successfully (Varsity a/c) 100 hrs
Staff training appointment (Varsity a/c) 400 hrs
Operational conversion and squadron (Hercules a/c) 150 hrs

No airsickness: during squadron flying in all weather conditions.

TREATMENT PATTERN

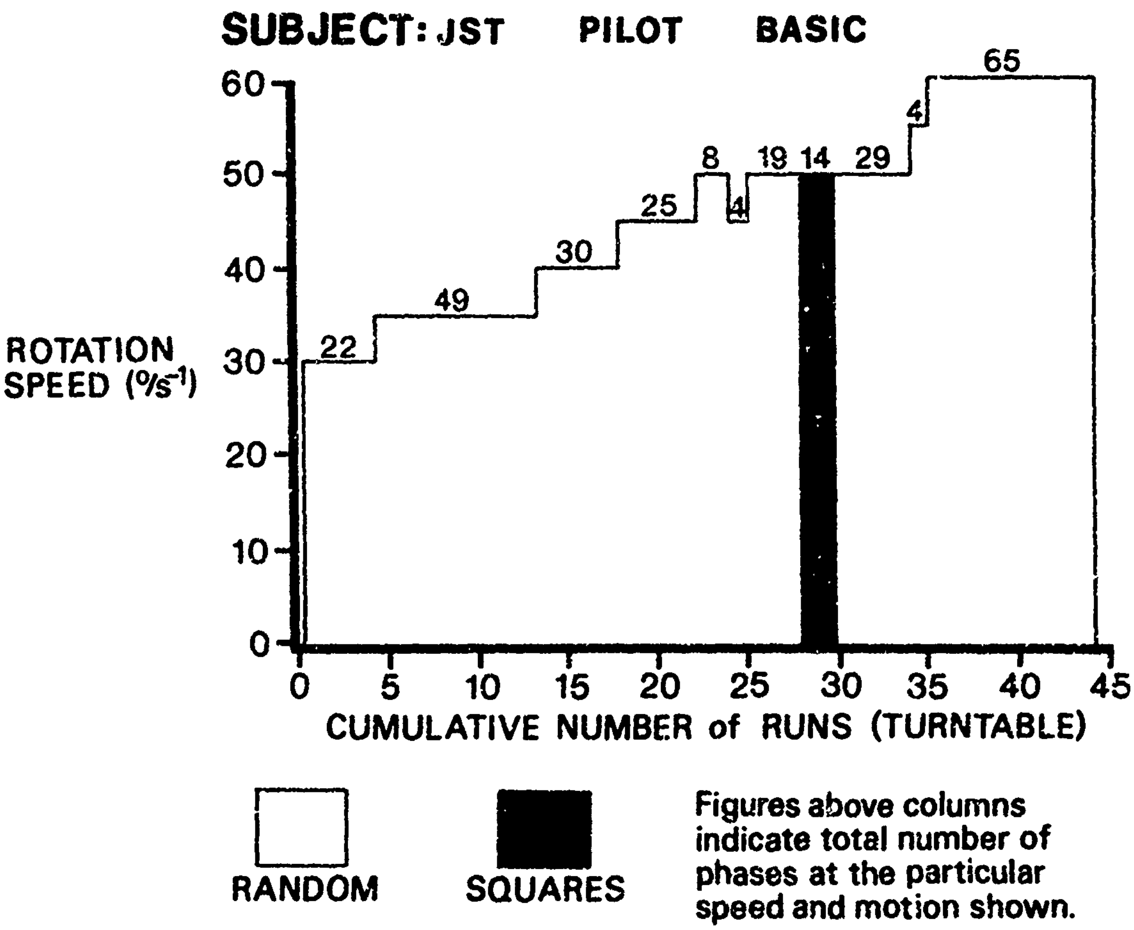

Fig. 10

SUMMARY OF TREATMENT: Subject JST

Turn-table:	Number of runs	44
	Total number of phases	269
	Average number of phases per day	10.8

Symptoms during Runs:

Symptom	Number of Runs
Nausea	36 (began on 1st run)
Dizziness	26) (began on 2nd run)
Confusion	2)
Sweating	8 (began on 1st run)
Abort	2 (9th and 28th runs)

CASE REPORT No. 4

Subject: AEW

Pre-entry Flying Experience: Powered flight: ATC Passenger 100 hrs
PFL (dual & solo) 40 hrs

Date of last flight: 10 months ago

CODE: PFE 2

Pre-entry History of Motion Sickness: Airsickness - occasional as passenger
Other forms of transport - nil
Swings, etc. - nil

CODE: PHMS 1

Cupulogram Characteristics on Entry: Slope 10.9s
Threshold $2.20^{o}s^{-1}$

Airsickness during Flying Training: 2nd trip in a Jet Provost abandoned due to airsickness; airsick on 75% of trips during first 35 hrs training flying except when flying in the airfield circuit. Treated with cyclizine hydrochloride (50 mg) before 5 dual trips without success. Minimal nausea before onset of vomiting. Typically 10s from feeling well to vomiting with only intermediate salivation. (CODE: SHAS 2)

Course of Treatment: AEW's course of treatment, which is summarised in Fig. 11, extended over 26 days. There was a major hold-up between runs 10 and 18 at a turn-table speed of $45^{o}s^{-1}$. Patient became confused which necessitated substituting 'square' patterns in place of 'random' maneouvres in order to make progress. Observed to be very tense during the turn-table maneouvres. Experienced lower bowel discomfort during 2nd week of treatment.

Rehabilitation Flying: 26 sorties (as per instructions in appendix) under the supervision of a selected qualified flying instructor on Standards Squadron at his own unit. Progress was slow but AEW was finally returned to routine flying training.

Follow-up: Completed basic training successfully (Jet Provost a/c) 110 hrs.
Finalist in the Aerobatic Trophy Competition.
Completed advanced training and squadron (Varsity a/c) 100 hrs.
Operational conversion and squadron (Hercules a/c) 170 hrs.

No airsickness during routine training since treatment. One isolated incident when his Instructor first demonstrated an aggressive aerobatic sequence when AEW was first selected to enter the aerobatic competition.

TREATMENT PATTERN

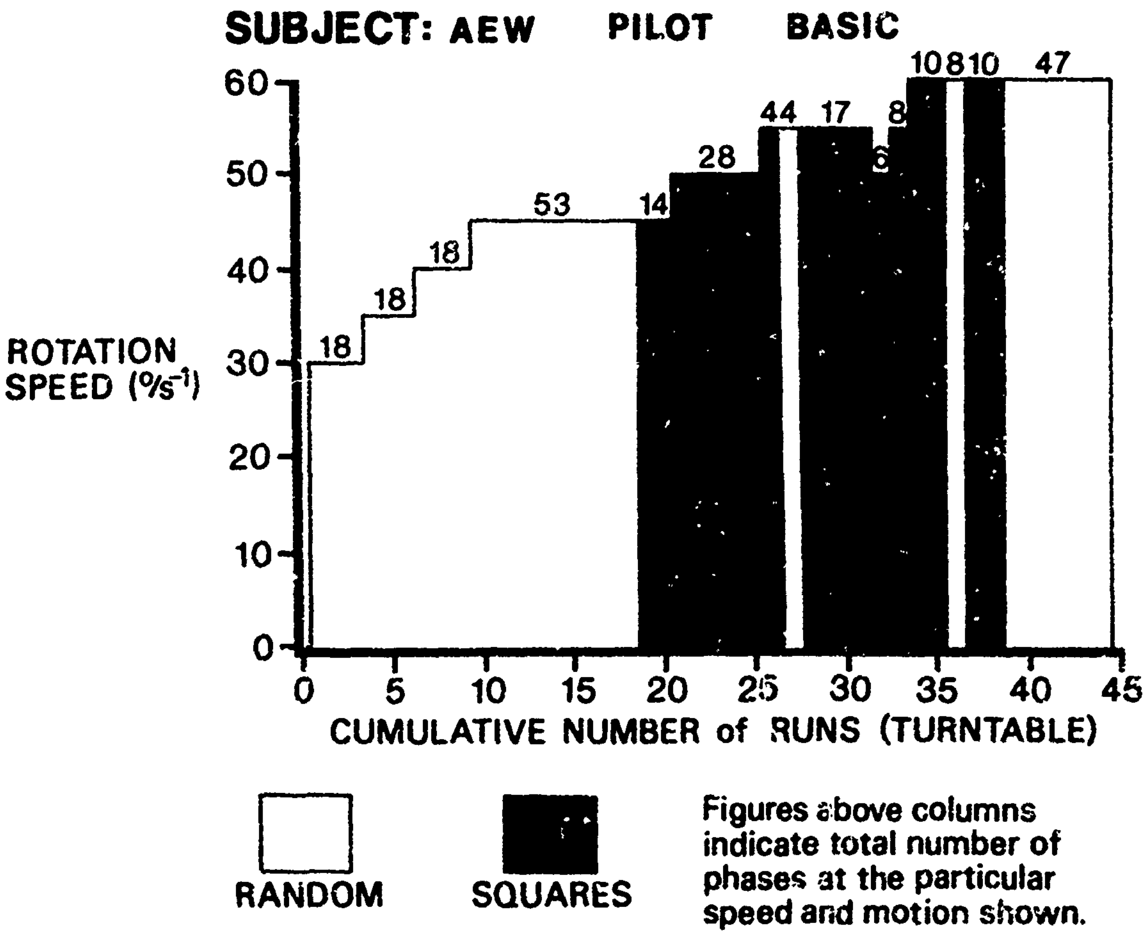

Fig. 11

SUMMARY OF TREATMENT: Subject AEW

Turn-table:	Number of runs	44
	Total number of phases	263
	Average number of phases per day	10.1

Symptoms during Runs:

Symptom	Number of Runs
Nausea	28 (began on 6th run)
Dizziness	22 (on most runs at $45^{\circ}s^{-1}$)
Confusion	10 (began on 4th run)
Sweating	4 (began on 8th run in conjunction with 'confusion')
Abort	0

CASE REPORT No. 5

Subject: RVWW

Pre-entry Flying Experience: Nil

CODE: PFE 0

Pre-entry History of Motion Sickness: Vehicle sickness - severe up to age 11 yrs - was given "anti-motion sickness pills"

Seasickness - little experience: no sickness but felt "uneasy"

Swings etc. - nil

CODE: PHMS 1

Cupulogram Characteristics on Entry: Slope 4.5s
Threshold $3.5^{\circ}s^{-1}$

Airsickness during Flying Training: 9 sorties were aborted out of the first 22 dual sorties (20 hrs) at RVWW's request because of nausea and discomfort; he vomited once. He was unable to maintain safe control of the aircraft during an attack. His instructors have frequently reported that he was tense and anxious in the air and "obsessed with the possibility of airsickness". Hyoscine hydrobromide (0.5 mg) failed to alleviate his symptoms. (CODE: SHAS 2).

Course of Treatment: RVWW underwent a course of treatment on the turn-table during his initial flying on Chipmunk a/c (details in Fig. 12). His airsickness returned during his basic flying training on Jet Provost a/c and he was given additional treatment.

Rehabilitation Flying: Given 20 hrs flying under supervision of a medical officer (pilot). Although this followed the general pattern laid down in appendix, the continuity of flying was poor due to adverse weather conditions.

Disposal: Permanently removed from flying training due to intractable airsickness at the Basic Flying Training School (Jet Provost a/c) - transferred to a ground appointment.

TREATMENT PATTERN
(Initial Course of Treatment)

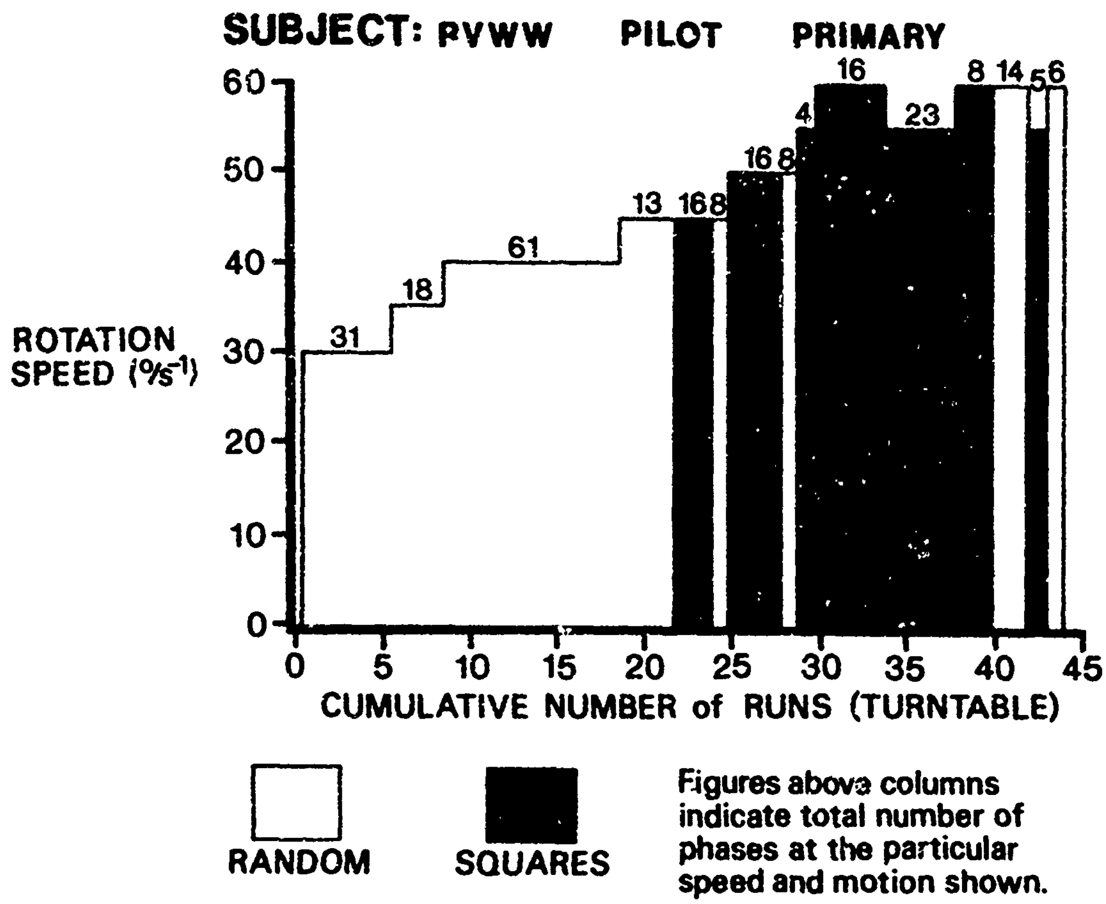

Fig. 12

SUMMARY OF TREATMENT: Subject RVWW

		Initial Treatment	Follow-up Treatment
Turn-table:	Number of runs	43	24
	Total number of phases	247	172
	Average number of phases per day	9.4	13.2

Symptoms	Number of Runs: Initial Treatment	Follow-up Treatment
Nausea	43 (every run)	20 (from 2nd run)
Dizziness	30 (from 1st run)	20 (from 1st run)
Confusion	0	0
Sweating	2 (towards end)	0
Abort	0	1 (at $50^{o}s^{-1}$; 7th run)

CASE REPORT No. 6

Subject: DMI

Pre-entry Flying Experience: Powered flight: Passenger - 80 hrs

Date of last flight: 5 years ago

CODE: PFE 1

Pre-entry History of Motion Sickness: Airsickness - all forms of air transport
Vehicle sickness - when passenger

CODE: PHMS 2

Cupulogram Characteristics on Entry: Slope 5.9s
Threshold $5.0^{o}s^{-1}$

Airsickness during Flying Training: Numerous episodes of nausea and vomiting from his first flight in a Jet Provost. Despite careful handling by his instructor DMI was removed from training after 40 hours flying because of "persistent airsickness". He was then transferred to another branch of the RAF for ground duties. (CODE: SHAS 2).

Three years later DMI was reconsidered for a return to flying training and referred for 'desensitisation' prior to the final decision being made.

Course of Treatment: DMI underwent a length course of 'treatment' on the turn-table over a period of 3 months, (see Fig. 13).

Rehabilitation Flying: 8 trips in a Jet Provost (6hr 45 min) with a Medical Officer (Pilot) at Central Flying School. The principles laid down in the appendix were implemented but continuity was poor because of weather conditions and DMI's representative sports commitments. He did not reach a satisfactory standard of flying and was not recommended for a return to flying training.

Disposal: Not accepted for flying training - left the Royal Air Force.

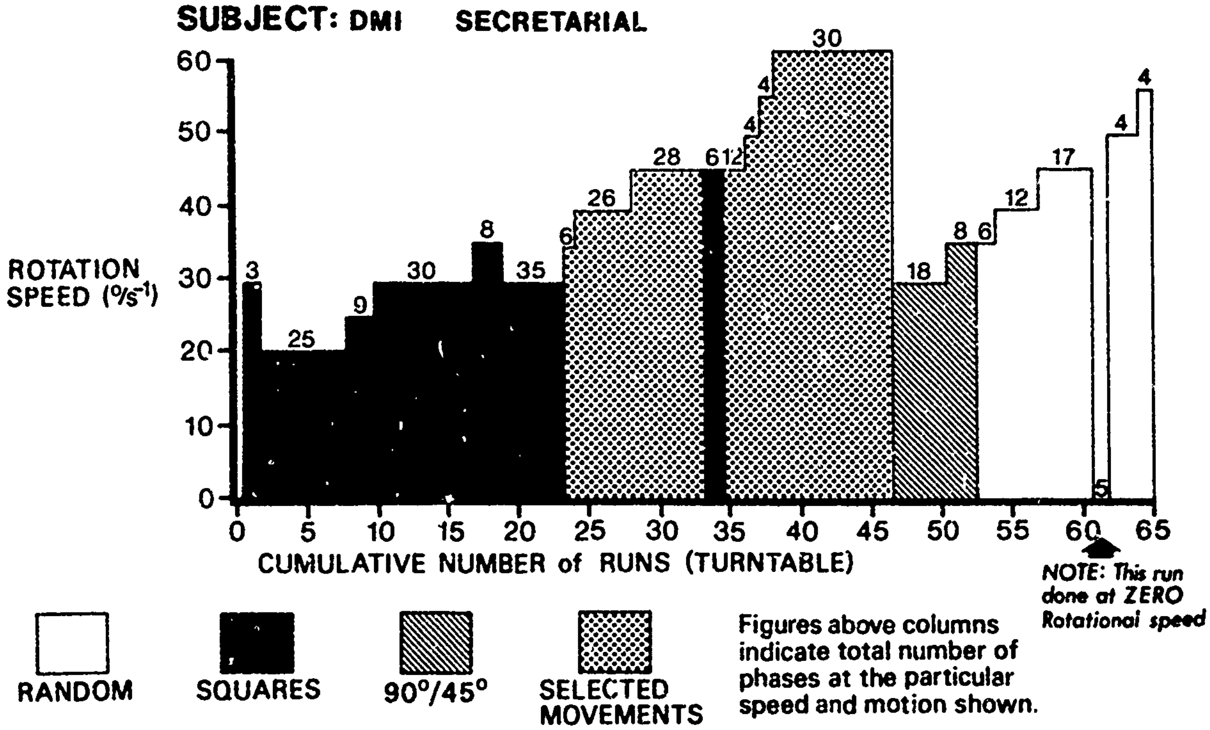

Fig. 13

<u>SUMMARY OF TREATMENT:</u> Subject DMI

<u>Turn-table:</u>

	Number of runs	64
	Total number of phases	300
	Average number of phases per day	6.2

NOTE: Runs were specially modified from the first abort.

<u>Symptoms during Runs:</u>

<u>Symptom</u>	<u>Number of Runs</u>
Nausea	51 (began on first run: marked nausea even at rotation speed of $20^{o}s^{-1}$)
Dizziness	5 (beginning on first run)
Confusion	6 (began on 8th run)
Sweating	3 (only late on in treatment)
Abort	3 (including first 2 runs)

CASE REPORT No. 7

Subject: JRI

Pre-entry Flying Experience: Nil

CODE: PFE 0

Pre-entry History of Motion Sickness: Vehicle sickness - marked on buses up to age of 10 yrs

CODE: PHMS 1

Cupulogram Characteristics on Entry: Slope 12.6s
Threshold $7.3^{o}s^{-1}$

Airsickness during Flying Training: A navigator who was airsick on about 20% of his training sorties in Varsity a/c. He completed the course and proceeded to the Canberra Operational Conversion Unit. Became severely airsick on first 4 sorties which had a markedly adverse effect on his ability to carry out his task.

Course of Treatment: JRI was treated on the turn-table as shown in this case report. On two occasions during his period of treatment he was referred to clinical consultants because of intercurrent illnesses. These illnesses meant that his course of treatment was spread over nearly 3 months, (see Fig. 14).

Rehabilitation Flying: 10 sorties in Jet Provost a/c (7½ hrs) and 1 in a Varsity a/c (1½ hrs) at Central Flying School under supervision of Medical Officer (Pilot) (c.f. appendix).

Follow-up: Grounded Permanently Unfit aircrew because of:

(1) Airsickness with marked phobic element
(2) Temperamentally unsuited to aircrew duties.

TREATMENT PATTERN

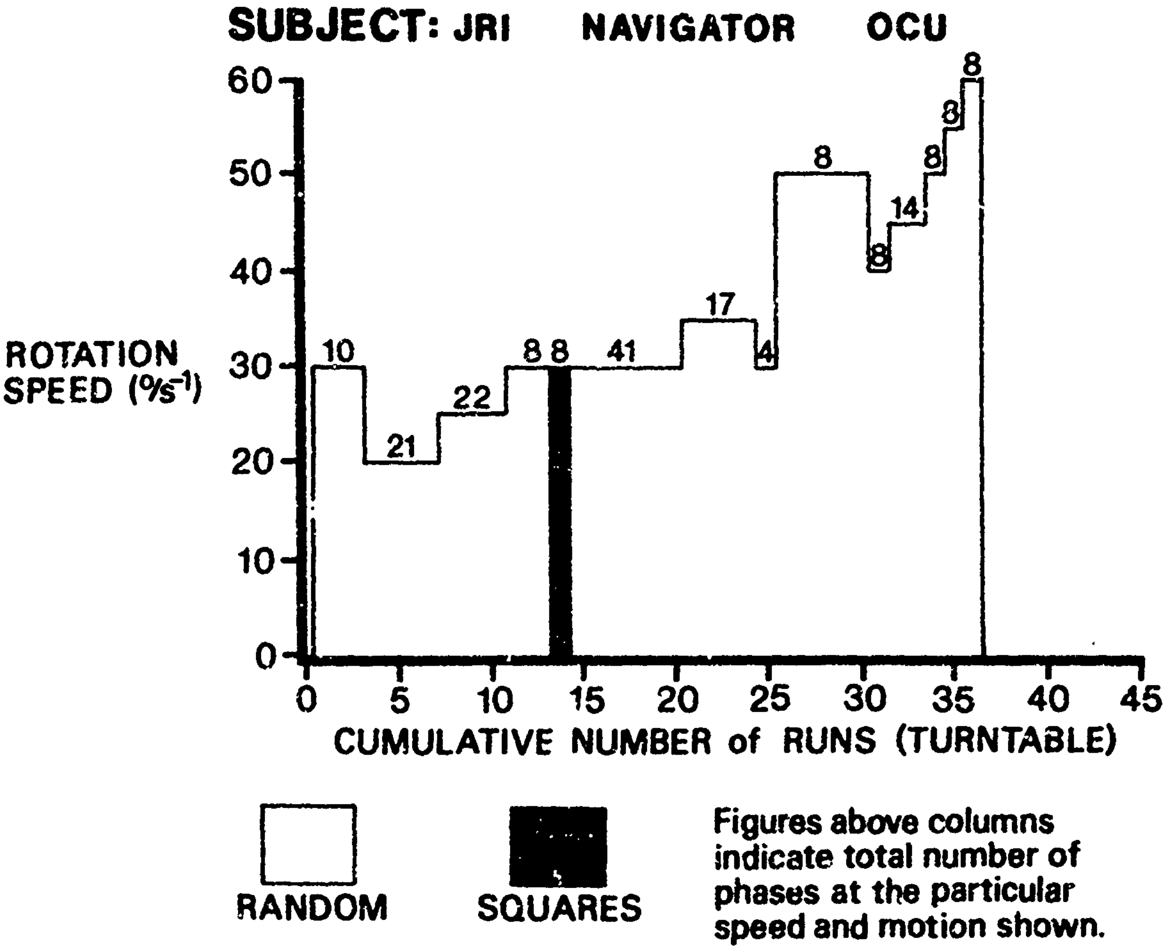

Fig. 14

SUMMARY OF TREATMENT: Subject JRI

Turn-table:	Number of runs	37
	Total number of phases	185
	Average number of phases per day	7.7

Symptoms during Runs:

Symptom	Number of Runs
Nausea	20 (from 1st run)
Dizziness	8 (from 1st run ac $20^{o}s^{-1}$)
Confusion	0
Sweating	4 (late in treatment programme)
Abort	6 (including 2nd and 3rd runs at $30^{o}s^{-1}$)

CASE REPORT No. 8

Subject: PI

Pre-entry Flying Experience: Nil

CODE: PFE 0

Pre-entry History of Motion Sickness: Vehicle sickness - 1 incident as a child

CODE: PHMS 1

Cupulogram Characteristics on Entry: Slope 14.0s
Threshold $5.0^{o}s^{-1}$

Airsickness during Flying Training: As an RAF apprentice PI was given a few hours air experience in Chipmunk a/c and on gliders. He had no airsickness even during aerobatic maneouvres. He was selected for aircrew and sent to Cranwell to fly Jet Provost a/c. During 1st trip he was shown aerobatic maneouvres and was not airsick. On the 2nd trip he was airsick when he experienced positive accelerations. His airsickness became worse and was not controlled by hyoscine hydrobromide (0.5 mg). CODE: SHAS 2.

Course of Treatment: PI's course of treatment lasted 2 weeks and the pattern is shown in the accompanying diagram. He only experienced mild symptoms during Coriolis vestibular accelerations and had no difficulty with progressive increases in stimulus, (see Fig. 15).

Rehabilitation Flying: 12 hrs Jet Provost a/c (c.f. appendix)

Follow-up: Completed basic training successfully (Varsity a/c) 100 hrs
Holding Unit (Dominie & Chipmunk a/c) 230 hrs
Operational conversion and Squadron (Shackleton a/c) 800 hrs

No problem with airsickness since leaving RAF Cranwell.

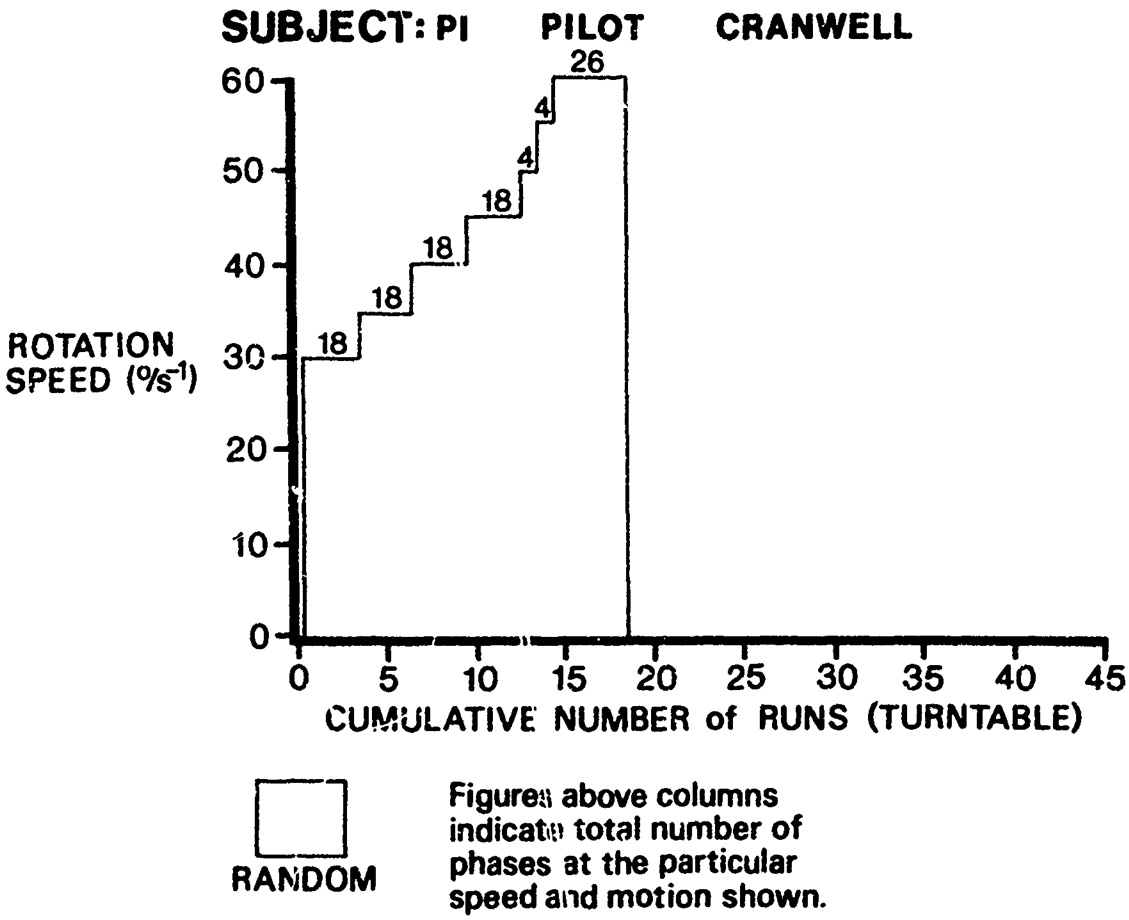

Fig. 15

SUMMARY OF TREATMENT: Subject PI

Turn-table:	Number of Runs	18
	Total number of phases	106
	Average number of phases per day	10.6

Symptoms during Runs:

Symptoms	Number of Runs	
Nausea	3)	
Dizziness	10)	
Confusion	11)	MILD
Sweating	1)	
Abort	0	

CASE REPORT No. 9

Subject: CDC

Pre-entry Flying Experience: Powered flight: Cessna Tripacer - 60 hrs (dual and solo) Private pilot's licence

Date of last flight: 6 months ago

CODE: PFE 2

Pre-entry History of Motion Sickness: Airsickness - not as passenger but required treatment when having dual aerobatics

Seasickness - sick in rough seas en route to Australia

Vehicle sickness - frequent when travelling in back seat of car up to 12 yrs of age

CODE: PHMS 2

Cupulogram Characteristics on Entry: Slope 15.4s
Threshold $3.5^{o}s^{-1}$

Airsickness during Flying Training: Airsickness during first 30 hrs flying in Jet Provost a/c at Basic Flying Training School, especially associated with maneouvres in the pitching plane. CODE: SHAS 2.

Course of Treatment: CDC underwent a short course of treatment on the turn-table: his treatment pattern is shown in this report. He had few symptoms during exposure to Coriolis vestibular acceleration and progressed rapidly to maximum turn-table speed, (see Fig. 16).

Rehabilitation Flying: 8 sorties at his own unit under the supervision of a selected qualified flying instructor; pattern of flying as laid down in appendix.

Follow-up: Completed basic training successfully (Jet Provost a/c) 120 hrs
Competed for Course Aerobatic Trophy
Completed advanced training successfully (Hunter a/c) 110 hrs
Operational conversion and squadron (Hunter and Lightning a/c) 300 hrs

No airsickness on high performance Lightning fighter aircraft.

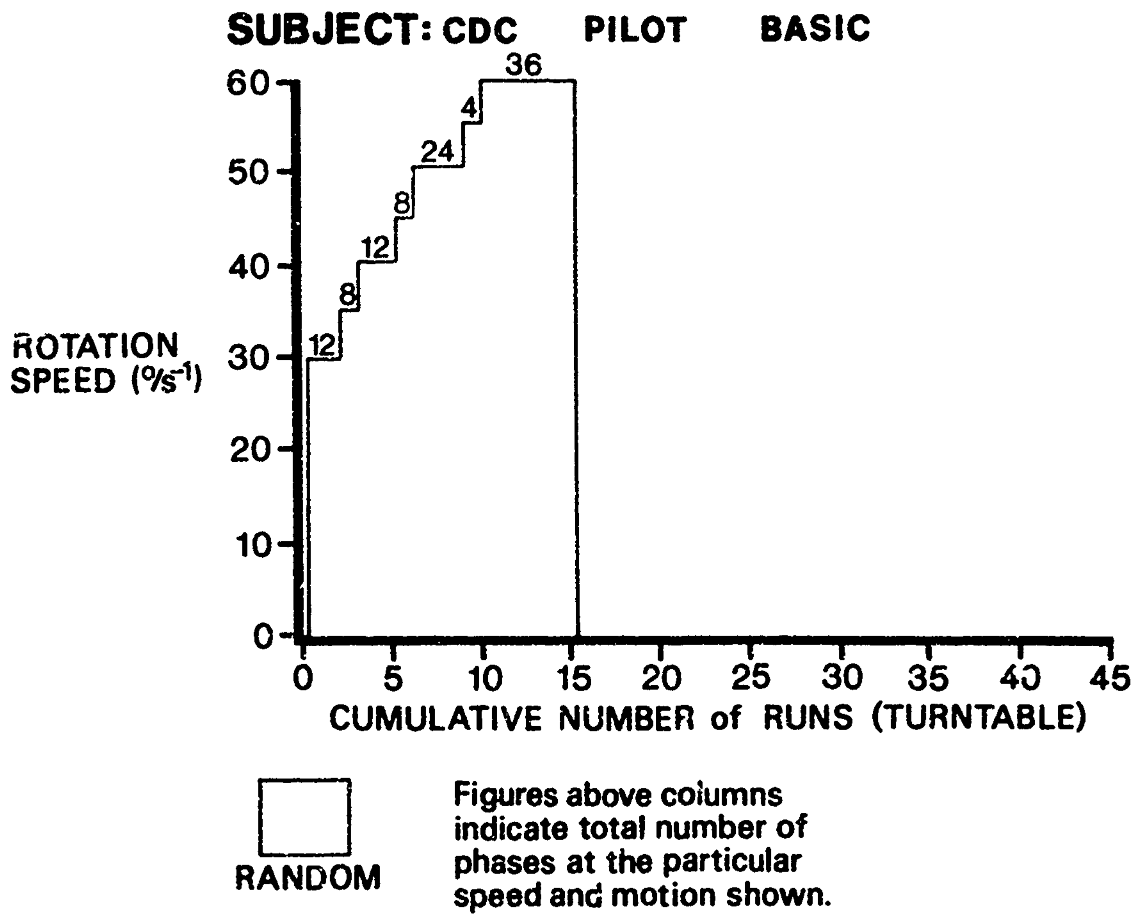

Fig. 16

SUMMARY OF TREATMENT: Subject CDC

Turn-table:	Number of runs	16
	Total number of phases	104
	Average number of phases per day	11.6

Symptoms during Runs:

Symptom	Number of Runs	
Nausea	1)	
Dizziness	5)	
Confusion	0)	mild
Sweating	1)	
Abort	0	

CASE REPORT No. 10

Subject: RAC

Pre-entry Flying Experience: Nil

CODE: PFE 0

Pre-entry History of Motion Sickness: Seasickness - marked on cross-channel ferry and when sailing

Vehicle sickness - cars up to age of 12 yrs

Roundabouts - "more than average discomfort"

CODE: PHMS 2

Cupulogram Characteristics on Entry: Slope 6.9s

Threshold $1.5^{o}s^{-1}$

Airsickness during Flying Training: On average RAC was airsick on 15% of his navigational training flights on Varsity a/c. On 3 trips his performance decrement was so severe that he had to be removed from his task. He completed his training but was referred for treatment because he had been selected for navigational duties in a high performance a/c which was known to provoke airsickness. (CODE: SHAS 2).

Course of Treatment: RAC underwent a short course of treatment on the turn-table; details are shown in the accompanying diagram, (see Fig. 17).

Rehabilitation Flying: 10 hrs 25 mins on Jet Provost a/c at the RAF Central Flying School with Medical Officer (Pilot). (c.f. appendix).

Follow-up: Completed 600 hrs on Sea Vixen high performance a/c

Selected for further operational duty on F4 high performance fighters

No airsickness during high performance Squadron flying.

TREATMENT PATTERN

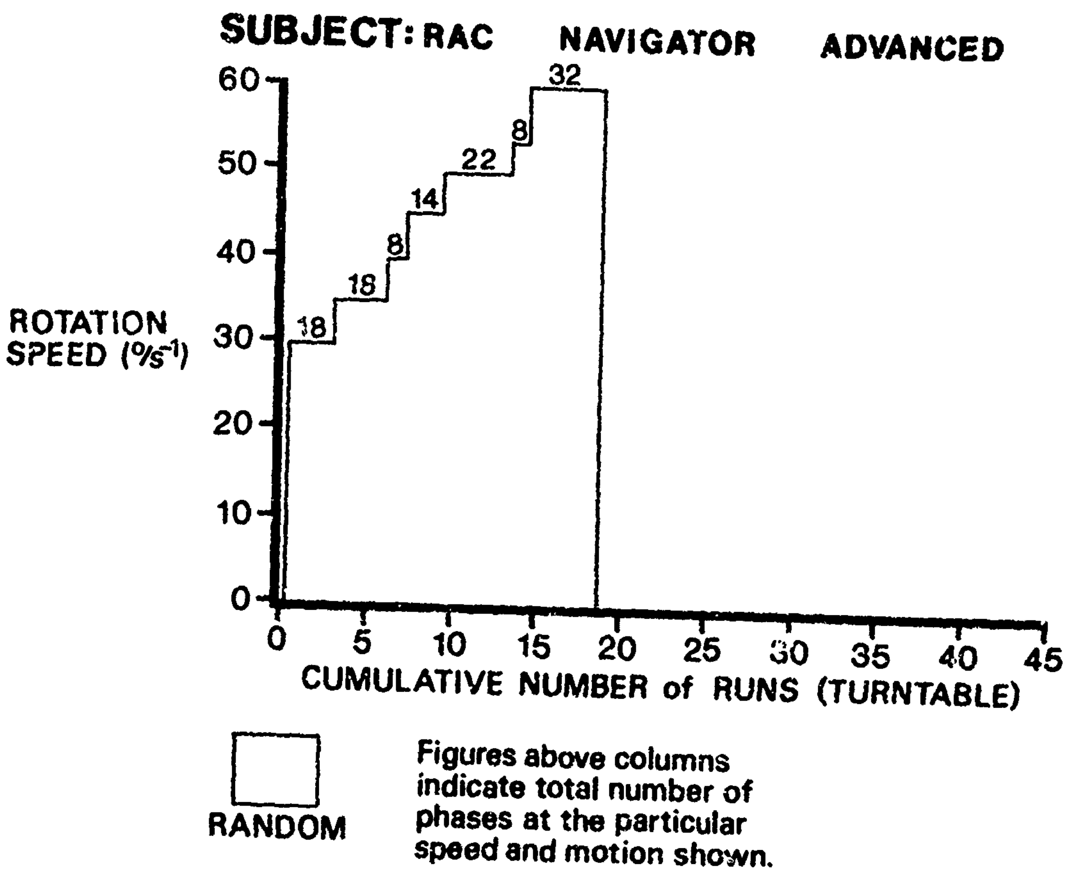

Fig. 17

SUMMARY OF TREATMENT: Subject RAC

Turn-table: Number of runs 18

Total number of phases 120

Average number of phases per day 10.9

Symptoms during Runs:

Symptom	Number of Runs	
Nausea	10)	
Dizziness	2)	began on first runs - most severe
Confusion	5)	at $50^{\circ}s^{-1}$ rotation speed
Sweating	4)	
Abort	0	

Varsity aircraft.

There have always been student pilots who seem more suited to the high performance 'fighter-type' of flying and others who were so-called 'bomber/transport types'. This is certainly not a direct reflection of their susceptibility to airsickness although the occurrence of airsickness in the early stages of training may have the effect of putting an individual off high performance aircraft which they associate with aerobatic manoeuvres.

RVWW (case report no. 5) shows a treatment pattern (Fig. 12) very similar to that followed by AEW except that he was not able to sustain random maneouvres for a number of runs at a rate of rotation of $60^{o}s^{-1}$. The fact that RVWW had to have a run of 'square' pattern movements in his 43rd run shows that he was not sufficiently adapted to be comfortable in that situation. When a patient has been under treatment for this length of time one is tempted to allow him to start remedial flying as soon as he expresses a wish to do so; in retrospect this may well be a mistake. RVHW subsequently experienced a return of airsickness during basic flying. He was given a second course of treatment but this is not shown in this figure.

DMI (case report no. 6) was also a failure in that the treatment did not overcome his airsickness. His programme was very much modified by his adverse reaction to the vestibular stimulus and a long period of 'selected maneouvres' was added to his treatment, (Fig. 13). In these, the majority were a 'square' pattern and the operator added the occasional 'diagonal' movement if the subject seemed well enough to cope with it. It is clear from the response of the majority of patients that such an extended treatment, lasting 65 runs, is both uneconomical and unlikely to be successful.

JRI (case report no.7) had two breaks in treatment due to intercurrent illnesses but his pattern of treatment (Fig. 14) has been shown as a continuum for comparison with other patients. He abandoned both his second and third runs at $30^{o}s^{-1}$ and for this reason the turn-table speed was reduced to $20^{o}s^{-1}$ and he was not able to get beyond $30^{o}s^{-1}$ until his 20th run. In this respect, his early responses were similar to those of DMI but unlike the latter patient he was able to make rapid progress towards the end of his treatment, completing movements at 50, 55 and $60^{o}s^{-1}$ on successive runs with no difficulty. This apparent discontinuity in tolerance suggests that psychiatric factors were presumably responsible for his disability. At the same time the author felt that JRI had decided to 'get away' from the turn-table because his responses to treatment were not going to be useful as a means of treating his real problem. He did not like the Canberra aircraft; he did not like navigating and indeed probably wanted to get out of flying altogether. He perhaps saw the airsickness treatment programme as a means of achieving this. Because of the experimental nature of the programme there was no finite end point and on each occasion that he presented with another excuse, namely an illness, he always finished up back on the turn-table. It was on his return from his second stay in hospital that he made such apparently rapid progress and completed his treatment. When he returned to flying he made numerous representations to become a pilot and eventually was removed from his navigational training course. He was subsequently down-graded medically as being unsuitable for aircrew and left the service.

PI (case report no. 8) proceeded through his treatment programme with the minimum of disturbance. He first experienced nausea at a turn-table speed of $40^{o}s^{-1}$, then $55^{o}s^{-1}$ and for the third and last time at $60^{o}s^{-1}$. His other symptoms of motion sickness were also extremely mild.

He was noticeably anxious and was an ex-apprentice specially chosen for pilot training at the RAF College Cranwell. The latter is a position which must have created a stressful situation for someone intent on 'making good'. These factors, together with the response to treatment shown in Fig. 15, strongly suggest that his 'sickness in the air' was a stress response rather than a typical manifestation of motion stimuli.

CDC (a pilot, case report no. 9) and RAC (a navigator, case report no. 10) show a similar pattern (Figs. 16 & 17). They both had intractable airsickness, responded quickly on the turn-table and are now flying very high performance aircraft successfully. They are both completely free of airsickness.

CDC made the following comments:

"In my opinion this improvement (in his susceptibility to airsickness) was due to two main factors. Firstly I feel that your treatment had provided me with a lot more confidence in the air and secondly, my instructors were aware of my problems and as a result allowed me to do as much flying as possible myself; a factor which in my case has always been a great help." (This did not mean that his flying training was less 'aggressive' than usual; he competed for the Aerobatic Trophy).

CDC mentioned the word confidence a lot in his follow-up letters and having finally got confidence in himself as a good pilot he had no further problems with airsickness even when he first converted to the high-performance Lightning aircraft.

RAC was a very good trainee navigator who set himself a very high standard. In this respect, every navigation sortie in a Varsity aircraft was both a challenge and an examination and just as he was sick before scholastic examinations when young, why not now in the airborne situation? Certainly he improved dramatically when he gained insight into the causes of his own airsickness following a lengthy discussion on his personality with the author. This was shown by his greatly improved response on the turn-table from the 13th run onwards, (see Fig. 16). Subsequently he was able to carry out his navigational duties in high performance fighter aircraft, flying from an aircraft carrier, without sickness.

Results of Treatment:

The results obtained in treating the first 50 consecutive and unselected patients by this method are shown in Table 15. 38 patients (76%) suffering from intractable airsickness were returned to full unrestricted flying. A further 5 patients (10%) who failed flying training after treatment did so for reasons which, in the opinion of their executive supervisors and qualified flying instructors, were unrelated to airsickness. Hence the 'cure rate' can be assessed at 86%. Even at the lower figure of 76% the success rate for the completion of flying training is higher than the overall training success rate and indicates that the trainees who had to be treated for intractable airsickness were above the average in other respects. A conclusion that was supported by the follow-up study.

Examination of the 50 treatment patterns suggests that they give a good indication of the ultimate outcome in the majority of cases. There is inevitably a 'grey area' because in patients who are slow to adapt to Coriolis vestibular acceleration the cut-off point will have to be decided with due regard to other factors such as the individual's academic and flying ability. This is a direct parallel with the problem of setting up selection tests to exclude individuals who are prone to motion sickness. The higher the standard, or the shorter the time allowed for treatment, the greater will be the number who fail. It is encouraging to note that patients JST and AEY (see Fig. 7) who made slow but steady progress (taking 44 runs to complete treatment) ultimately became successful operational pilots. In contrast, the small group in whom treatment was unsuccessful exhibited characteristic features. These consist of an erratic and limited development of adaptation in patients who also seemed to lack enthusiasm for flying and prevaricated in response to direct questioning about accepting treatment. For this reason, the new treatment technique can be used as a combined 'evaluation/treatment technique'. The response of the individual during the first 10 runs, together with other salient features concerning his motivation give a useful indication as to whether or not it is likely to be worthwhile proceeding with treatment.

CLASS	TOTAL	PASS	FAIL	
			NOT AIRSICK	AIRSICK
STUDENT AIRCREW	44	34	4 (1)	6 (2)
QUALIFIED AIRCREW	6	4 (5)	1 (3)	1 (4)
ALL	50	38	5	7

Table 15.

Results of treatment - first 50 consecutive and unselected cases

Note:

(1) 3 failed because of poor airwork and 1 left the Service for family reasons. None of these suffered from airsickness.

(2) 2 admitted that they had begun to dislike flying prior to being exposed to any violent aerobatic maneouvres or suffering from any symptoms of airsickness.

(3) Failed because of poor airwork - no signs or symptoms of airsickness

(4) Marked phobic element in this case.

(5) 2 of these cases showed evidence of phobia related to a particular aircraft type.

Review of Mechanism of Treatment

The author was very interested to know how much of the success of this treatment was psychiatric in terms of deconditioning (a phobic anxiety or neurotic response) and how much was psychological, manifest as adaptation to a Coriolis vestibular stimulus. It is difficult to evaluate this problem and in the face of the high success rate it seemed unethical to modify the programme significantly in order to answer this question.

There were two 'units' in this programme; the author as a therapist/father figure (being senior in rank and an experienced aviator) and the tilting/turn-table. To exclude the author would not answer the question because the turn-table can be used to boost confidence as well as a means of inducing adaptation. One patient (ME) who received the usual interview could not start his turn-table exposures straight away for purely administrative reasons. By the time that he was available (3 weeks later) he did not need it. He had gained confidence and was no longer airsick (this also occurred in another case later). Recent investigations, using a medical officer other than the author, have shown that this technique can still be used successfully if the medical officer is well versed in this new method of treatment.

Another interesting case was SN, an army student pilot who was particularly

underconfident. He had come from a poor background and experienced many social difficulties. His selection to become an army pilot was almost beyond his wildest expectations. He completed his course on the turn-table well and stated that he had insight into his problem which was predominantly one of underconfidence rather than sensitivity to motion. As he was leaving the consulting room after the final interview he suddenly said:

"The only trouble is that at my flying school they may even fail you during the last week of training."

He was reminded that this outburst was merely another example of his lack of confidence and on that note he departed.

Three weeks later the author happened to meet the Army Specialist in Aviation Medicine who said:

"I'm sorry to tell you that SN isn't doing so well and we gave him every opportunity."

It transpired that the significance of this misguided help was that SN was returned to the Chief Instructor of the Flying School rather than his usual Flying Instructor. The author telephoned to SN immediately and simply said:

"The Army authorities have changed your instructor in good faith, believing that this would help you. This was not my recommendation, indeed if I had been asked, I would have disagreed with the decision because I believe that you may have misunderstood the reason. Let me say that if you think that this is merely an attempt to assess you with a view to suspension from training you are wrong. If the Army had been so inclined it could have done so by drawing a line through your name weeks ago without going to all this trouble."

SN has not been airsick since then.

These examples typify the cases whose sickness in the air is only marginally related to vestibular stimuli, if at all. As individuals they are predominantly underconfident in their ability to reach or live up to the high standards they set for themselves.

However important the 'seed' may be in terms of a changing Coriolis vestibular acceleration, the significance of the 'soil', the individual's personality, must be recognised as a most important factor. The way in which an individual 'handles' the sensory mismatch will influence greatly the severity of his airsickness.

Appendix

RETURN TO FLYING TRAINING FOLLOWING TREATMENT FOR AIRSICKNESS

The objective of this period of rehabilitation flying was to achieve a return to normal flying training progressively over a period of two weeks.

During the early stages of a gradual return to normal training those maneouvres known to precipitate airsickness in a particular individual were avoided, thereby allowing him to regain his 'air-legs' without loss of confidence:

The scheme was divided into three stages:-

STAGE 1

A period of dual flying during which all maneouvres known to make the individual airsick were avoided completely. The student was briefed to the effect that he would carry out a number of dual sorties in order to get his 'hand in' again. The content of the sorties was made known to him during the pre-briefing so that he would realise that he had no need to be anxious about 'uncomfortable' maneouvres.

On the successful completion of STAGE 1, the student proceeded to STAGE 2.

STAGE 2

As in STAGE 1 the main content of the sortie, other than those maneouvres known to provoke airsickness in this specific person, was left to the instructor so that he could achieve as much training benefit as possible. During this stage, however, maneouvres which had previously given rise to airsickness were introduced at the END of each sortie. It was stressed during the pre-flight briefing that these maneouvres would only be carried out at the end of each sortie. This was considered to be good for morale since the individual knew that he would land shortly after carrying out maneouvres which had previously caused airsickness. It also ensured maximum training time on each sortie even if minor upsets arose. During this period, the number of 'airsickness provoking maneouvres' were increased from one to three or four at the end of succeeding trips. Concurrently solo trips were also programmed if the individual was so cleared.

On the successful completion of STAGE 2, STAGE 3 was started.

STAGE 3

STAGE 3 was a natural extension of STAGE 2, during which the maneouvres previously carried out only at the end of each sortie were gradually brought forward into the body of the exercise, with the aim of achieving a normal exercise pattern by the end of this phase. Each sortie was carried out according to the student's pre-briefing and solo trips of a similar pattern were authorised where possible.

There are three points of note:

a. The importance, as ever, of a good student/instructor relationship aimed at encouraging the student.

b. The importance of a good, clear-cut, pre-flight briefing which on no account should be exceeded by the instructor in the air, no matter how well the individual seems to be coping with aerial maneouvres which had previously caused airsickness.

c. No attempt should be made, even in STAGE 3, to carry out types of maneouvres beyond the scope of the normal training syllabus. Far from 'proving a point' this might cause a serious and unnecessary relapse.

REFERENCES

Ambler, Rosalie, K. & Guedry, F.E. (1965). The validity of a brief vestibular disorientation test in screening pilot trainees. Jt. Report. US NAMI & NASA, NAMI 947. Pensacola Fla.

Aschan, G. (1954). Response to rotatory stimuli in fighter pilots. Acta. oto-lar. suppl. 116, 24-31.

Aschan, G., Nylen, C.O., Stahle, J. & Wersall, R. (1952). The rotation test: cupulometric data from 320 normals. Acta. oto-lar. 42, 451-459.

Benson, A.J. (1967). Postrotational sensation and nystagmus as indicants of semicircular canal function. Third symposium on the role of the vestibular organs in space exploration. NASA SP - 152, 421-432.

Benson, A.J. (1968). Vestibular asymmetry and spatial disorientation in aircrew. Proc. 39th Ann. Sci. Meeting, 258-259. Aerospace Medical Association.

Benson, A.J. (1973). Physical characteristics of stimuli which induce motion sickness: A review. IAM Report No. 532.

Benson, A.J., Goorney, A.B. & Reason, J.T. (1966). The effect of instructions upon post-rotational sensations and nystagmus. Acta. oto-lar. 62, 442-452.

Brand, J.J. & Perry, W.L.M. (1966). Drugs used in motion sickness. A critical review of the methods available for the study of drugs of potential value in its treatment and of the information which has been derived by these methods. Pharmacol. Rev. 18, 895-924.

Brand, J.J. & Whittingham, P. (1970). The use of intramuscular hyoscine in the control of motion sickness. IAM Report No. R481.

Brown, G.L. McCardle, B. & Magladery, J.W. (1942). Interim report on clinical investigations into airsickness. F.P.R.C. Rep. No. 410 (a).

Chinn, H.I. (1956). Evaluation of drugs for protection against motion sickness aboard transport ships. J. Am. Med. Assoc. 106, 755-760.

Clark, B. & Stewart, J.D. (1973). Relationship between motion sickness experience and tests of the perception of rotation in pilots and non-pilots. Aerospace Med. 44, 393-396.

De Wit, G. (1953). Seasickness (motion sickness). A labyrinthological study. Acta. oto-lar. suppl. 108, 7-56.

Dobie, T.G. (1965). Motion sickness during flying training. AGARD Conf. Proc. 2, 23-32.

Dobie, T.G. (1970). Airsickness during flying training. AGARD Conf. Proc. 61, AGARD-CP-61-70, 22, 1-3.

Dowd, P.J. (1964). Induction of resistance to motion sickness through repeated exposure to Coriolis stimulation. SAM-TR-64-87. USAF School of Aerospace Medicine, Brooks AFB.

Gellhorn, E. & Loofbourrow, G.N. (1963). In Emotions and Emotional Disorders. A neurophysiological study. 256-260. Harper & Row. New York.

Gillingham, K.K. (1966). A primer of vestibular function, spatial orientation, and motion sickness. Review 4-66. USAF School of Aerospace Medicine, Brooks AFB.

Graybiel, A., Deane, F.R. & Colehour, J.K. (1969). Prevention of overt motion sickness by incremental exposure to otherwise highly stressful Coriolis accelerations. Aerospace Med. 40, 142-148.

Guedry, F.E. (1965). Psychophysiological studies of vestibular function. In Contributions to sensory physiology; ed. W.D. Neff, New York: Academic Press.

Hall, G.E. (1942). The effect of position on the incidence of swing sickness. In: Proc. 7th meeting of the Sub-cttee on Personnel Selection Assoc. Cttee. on Av. Med. Res. N.R.C. of Canada.

Hardacre, L.E. & Kennedy, R.S. (1965). Some issues in the development of a motion sickness questionnaire for flight students. NSAM - 916. US Naval School of Aviation Medicine, Pensacola.

Hemrie, R.M. & Entwistle, I.R. (1968). Seasickness. B.M.J. 4, 514.

Hemingway, A. (1946). The relationship of airsickness to other types of motion sickness. J. Aviation Med. 17: 80-85 and 95.

Hulk, J. & Jongkees, L.B.W. (1948). The turning test with small regulable stimuli. II. The normal cupulogram. J. Lar. Otol. 62, 70-75.

James, W. (1882). The sense of dizziness in deaf-mutes. Am. J. Otol. 4, 239-254.

Johnson, W.H. & Mayne, J.W. (1953). Stimulus required to produce motion sickness. Restriction of head movement as a preventive of airsickness - Field Studies on airborne troops. J. Av. Med. 24, 400-411 and 452.

Johnson, W.H., Stubbs, R.A., Kelk, G.F. & Franks, W.R. (1951). Stimulus required to produce motion sickness. I. Preliminary report dealing with importance of head movements. J. Aviation Med. 22, 265-374.

Kennedy, R.S., Graybiel, A., McDonough, R.C. & Beckwith, F.D. (1965). Symptomatology under storm conditions in the North Atlantic in control subjects and in persons with bilateral labyrinthine defects. NSAM-928. United States Naval School of Aviation Medicine, Pensacola.

Lansberg, M.P. (1961). Canal sickness: fact or fiction. Rev. Med. Aero. 2. 171-178.

Miller, E.F. & Graybiel, A. (1969). A standardised laboraoty means of determining susceptiblity to Coriolis (motion) sickness. NAMI-1058, Naval Aerospace Medical Centre, Pensacola.

Miller, E.F. & Graybiel, A. (1970). A provocative test for grading susceptibility to motion sickness yielding a single numerical score. Acta. oto-lar. suppl. 274.

McNally, W.J. & Stuart, E.A. (1942). Physiology of the labyrinth reviewed in relation to seasickness and other forms of motion sickness. War Med. 2: 683-771.

Money, K.E. (1970). Motion sickness. Physiol. Rev. 50.

Popov, A.P. (1943). Special vestibular training. In: Voyachek & Steiman's Fundamentals of Aviation Medicine, Chap. 19. University of Toronto Press.

Powell, T.J. (1954). Acute motion sickness induced by angular accelerations. F.P.R.C. 865.

Reason, J.T. (1970). Motion sickness: a special case of sensory rearrangement. Advmt. Sci., Lond. 26, 386-393.

Rubin, H.J. (1942). Airsickness in a primary air force training detachment. J. Aviation Med. 13, 272-276.

Sjöberg, A.A. (1931). Experimentelle studien über den auslosungsmechanismus der seekrankheit. Acta. oto-lar. suppl. 14, 1-136.

Tyler, D.B. & Bard, P. (1949). Motion sickness. Physiol. Rev. 29, 311-369.

Van Egmond, A.A.J., Groen, J.J. & Jongkees, L.B.W. (1948). The turning test with small regulable stimuli. I. Method of examination: cupulometria. J. Lar. Otol. 62, 63-69.

Whiteside, T.C.D. (1965). Motion sickness. In: Gillies' text-book of Aviation Physiology, 1st ed. chap. 27. edited by J.A. Gillies, Oxford: Pergamon Press.

Wood, C.D. (1964). Review of motion sickness drugs from 1954-1964. Special report 64-2. US Naval School of Aviation Medicine, Pensacola.

Wood, C.D. & Graybiel, A. (1968). Evaluation of sixteen anti-motion sickness drugs under controlled laboratory conditions. Aerospace Med. 39, 1341-1344..

Wood, C.D. & Graybiel, A. (1970). Evaluation of anti-motion sickness drugs. A new effective remedy revealed. Aerospace Med. 41, 932-933.